Computer-based Collaborative Concept Mapping: Motivating Indian Secondary Students to Learn Science

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Dedication

Dedicated to my Dad

who,

Lit the fire of learning in me;

Provided this opportunity to gain 'some knowledge';

and

Endlessly inspired me to

Excel personally and professionally.

Koti-koti dhanyawaad Pitaji!

and

Mum's blessings are *beyond words*.

Abstract

This is a study of the design, development, implementation and evaluation of a teaching and learning intervention. The overarching aim of the study was to investigate the effectiveness of the intervention 'Computer-based Collaborative Concept Mapping' (CCCM) on Indian secondary students' conceptual learning and motivation towards science learning. CCCM was designed based on constructivist and cognitive theories of learning and reinforced by recent motivation theories. The study followed a Design-based research (DBR) methodology. CCCM was implemented in two selected Indian secondary grade 9 classrooms. A quasi-experimental *Solomon Four-Group* research design was adopted to carry out the teaching experiment and mixed methods of data collection were used to generate and collect data from 241 secondary students and the two science teachers. The intervention was designed and piloted to check the feasibility for further implementation. The actual implementation of CCCM followed the pilot testing for 10 weeks. Students studied science concepts in small groups using the computer software *Inspiration*. Students constructed concept maps on various topics after discussing the concepts in their groups. The achievement test ATS9 was designed and administered as a pre-post-test to examine the conceptual learning and science achievement. Students' responses were analysed to examine their individual conceptual learning whereas group concept maps were analysed to assess group learning. The motivation questionnaire *SMTSL* was also administered as a pre-post-test to investigate students' initial and final motivation to learn science. At the end of the teaching experiment, the science teachers and two groups of students were interviewed. Analyses of the quantitative data suggested a statistically significant enhancement of science achievement, conceptual learning and motivation towards science learning. The qualitative data findings revealed positive attitudes of students and teachers towards the CCCM use. Students and teachers believed that CCCM use could promote conceptual learning and motivate students to learn science. Both students and teachers preferred CCCM over on-going traditional didactic methods of teaching-learning. Some enablers and barriers identified by teachers and students in the Indian science classroom context are also explored and discussed. A framework for enhancing secondary school students' motivation towards science learning and conceptual learning is proposed based on the findings. The findings of the study also contribute to addressing the prevailing *learning crisis* in Indian secondary school science classrooms by offering CCCM an active and participatory instructional strategy as envisioned by the Indian National Curriculum Framework 2005.

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Undertaking research is usually not an easy endeavour. I believe that the doctoral research is the most difficult because this is the stage most doctoral students are confronted with the nature, structure, process and experience for the first time. Generally, a doctoral student enters the world of research inexperienced, with an excitement and a vision in mind to improve the situation. For me, the completion of this study involved a good amount of blood, sweats and tears, although all of them were not mine. I am indebted to those who shared this portion and acknowledge the care, support and help which I received from those 'significant others'.

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Abbreviations used

ATS9	:	Achievement Test in Science, Grade 9
ASER	:	Annual Status of Education Report
CCM	:	Collaborative Concept Mapping
CCCM	:	Computer-based Collaborative Concept Mapping
DSEL	:	Department of School Education and literacy
GoI	:	Government of India
HOCS	:	Higher-order cognitive skills
IISER	:	Indian Institute of Science Education and Research
IISc	:	Indian Institute of Science
IIT	:	Indian Institute of Technology
INCF:	:	Indian National Curriculum Framwork
INSA	:	Indian National Science Academy
LOCS	:	Lowe-order cognitive skills
MHRD	:	Ministry of Human Resource Development
NAS	:	National Achievement Survey
NCERT	:	National Council of Educational Research and Training
NCFTE	:	National Curriculum Framework for Teacher Education
NCTE	:	National Council for Teacher Education
RAA	:	Rashtriya Avishkar Abhiyan (National Invention Campaign)

RMSA : Rashtriya Madhyamik Shiksha Abhiyan (National Secondary Education Campaign)

SSA : Sarv Shiksha Abhiyan (Education for All Campaign)

Chapter One. Introduction and Context

"What matters in learning science is not only what we know but how we know what we know and how that knowledge came to be. Anything less offers only a partial view of the achievements of science."

Osborne (2016, p. not given)

This chapter provides an introduction to the present study which is situated within the Indian science education context. It begins by highlighting the need to focus on Science and Technology education. A description of the Indian school education system and science education is provided. This is followed by a brief discussion of some of the challenges associated with Indian science education and the initiatives taken to deal with those challenges. From a secondary school teaching and learning perspective, the rationale for this research is presented. Next, the research aims are presented and the significance of the research to address the specific issues of conceptual learning and motivation towards science learning is outlined. Finally, the structure of the thesis is presented to provide a road map with signposts to assist the reader in navigating through the thesis.

1.1. Introduction

The emphasis on Science, Technology, Engineering and Mathematics (STEM) education in India and worldwide is well documented in education literature. Various reports such as *Successful K-12 STEM Education: Identifying Effective Approaches in Science, Technology, Engineering, and Mathematics* (National Research Council, 2011), *Prepare and Inspire: K-12 Science, Technology, Engineering, and Math (STEM) Education for America's Future* (President's Council of Advisors on Science and Technology, 2010), *India as a Global Leader in Science* (Science Advisory Council to the Prime Minister, 2010), and *Pursuit and Promotion of Science: The Indian Experience* (Indian National Science Academy, 2001) make strong cases to put emphasis on providing students with access to good quality STEM education. All of these reports consider success in the STEM disciplines as an important measure and indicator of the progress, economic development and competitiveness of a nation. While articulating the vision for Indian science as a global leader, the Science Advisory Council to the Prime Minister (2010) explicitly comments on the central role that science can play in national development. The council states:

> In the next two decades, India is likely to become an economically prosperous nation and move significantly towards being a far more inclusive society, with the bulk of its population gaining access to facilities for education and health care and living a life with hope and security. *To realize such a vision, it is essential that science is at the heart of the strategy that the next stage of national development demands*. In what follows, we present a vision for the growth of Indian science that can help the strategy succeed, and a road map for India to emerge simultaneously as a global leader in science. (p. i; emphasis added)

The Council's vision document further analyses the status of Indian science at the global level, describing the immense but unrealised Indian potential in science, indicating a strong faith in science, suggesting the way forward and finally recommending viewing science as a crucial agent of transformation.

One of the main reasons for this ever increasing emphasis on STEM education appears to be the pressure on governments "to produce technically skilled people" (Coll & Taylor, 2008, p. xi) who can actively participate in society and contribute to their respective economies. Another reason purported by Coll and Taylor (2004) is the current exposure of the general public to science education, more so than in the past. In the Indian context, it becomes imperative to emphasise STEM subjects as these are directly or indirectly associated with the growth of the large and fast growing Indian economy (Planning Commission Government of India, 2008, 2013b). In relation to the vital role that science can play in Indian social and economic development, the Indian National Curriculum Framework[1] (INCF; National Council of Educational Research and Training, 2005) document states that "In a progressive forward-looking society, science can play a truly liberating role, helping people escape from the vicious cycles of

[1]The term Indian National Curriculum Framework (INCF 2005) is used instead of National Curriculum Framework (NCF 2005) throughout this thesis for the ease of International readers.

poverty, ignorance and superstition" (p. 46). These observations of the strong emphasis placed on STEM subjects in the Indian context since the start of the 21^{st} century, therefore, indicates that science has the potential to help the growing Indian economy to realise the vision of a "leader in the scientific world, and a knowledge provider for the world" (Science Advisory Council to the Prime Minister, 2010, p. 33).

From time to time, the Government of India (GoI), through its various plans, policies and schemes (for example Five Year plans[2], Department of School Education and Literacy's campaigns and National Policies of Education) has placed strong emphasis on STEM related activities to promote science education in the country. The recent *11^{th}* (2007-2012) and *12^{th}* (2012-2017) *Five Year Plans* of the GoI have clearly stressed the development of STEM education and have recommended ways to improve the condition of the poor quality and declining standards of school science education. In relation to the importance of science and technology education in the Indian context, the report by the Indian National Science Academy (INSA, 2001) highlights:

> India has realized that in the emerging global scenario- wherein intellectual property will be highly valued and rights will be fiercely exploited and zealously guarded- the only way to improve the nation's competitiveness is through better and more productive science and technical education and flourishing scientific research and technological development. (p. 74)

Realizing this need to develop science and technology education, various departments of different ministries of the GoI have consistently prioritised science and technology in their action plans. Therefore, the GoI has heavily invested in STEM education and launched various schemes and campaigns such as Rashtriya Madhyamik Shiksha Abhiyan (RMSA; English name: National Secondary Education Campaign), Rashtriya Avishkar Abhiyan (RAA; English name: National Invention Campaign) and Kishore Vaigyanik Protsahan Yojana (KVPY; meaning Programme for Encouragement of Young Scientists) specially to promote and to improve the quality of school science education. However, to make science and technology education more productive as envisioned by the INSA (2001) there is a crucial need to revamp the school science

[2] Five Year Plans in India are prepared, organised and implemented by the Planning Commission of Government of India, in which mainly budgetary allocations of different sectors are made.

education curriculum (Indian National Science Academy, 2001; National Council of Educational Research and Training, 2005; Planning Commission Government of India, 2008, 2013b) to transform it into an engaging and joyful experience for students as recommended by the Indian National Curriculum Framework (National Council of Educational Research and Training, 2005).

In spite of this strong focus on STEM education in India, students' performance in science at secondary school stage has been a matter of concern (National Council of Educational Research and Training, 2009). The poor and declining science achievement levels both at primary (ASER, 2011, 2015; Srivastava, 2015) and secondary (Banerji, 2015; National Council of Educational Research and Training, 2014b, 2015; M. Walker, 2011) stages of schooling have raised 'big questions' about the curriculum (nature and implementation), pedagogy and methods of assessment prevalent in the Indian school education system. Moreover, a recent report by the United Nations Educational, Scientific and Cultural Organization (UNESCO, 2014) titled *Teaching and Learning: Achieving Quality for All* has highlighted the problem of learning in the Indian schooling context and recommended making learning outcomes and teaching-learning quality *national priorities* to end the persisting learning crisis. Another UNESCO report: *The Global Learning Crisis: Why every child deserve a quality education* (UNESCO, 2013) has described the prevailing learning crisis internationally and offered recommendations such as revision of the school curricula, improvement of the quality of learning resources, transformation of classrooms and improvement of teachers' working conditions, to improve the overall quality of learning in schools. A more recent report: *Education for All 2000-2015: Achievement and Challenges, EFA Global Monitoring Report 2015* by UNESCO (2015) examined the progress made by 164 countries (including India) towards achieving the six focussed goals of the 'Education for All' movement of UNESCO which were established in 2000 at the World Education Forum in Dakar, Senegal (see *Dakar Framework for Action, Education for All: Meeting our Collective Commitments* for details). This report described the achievement of most of the goals as satisfactory but stressed that there is a great deal of work to be done to enhance the quality of education (goal 6) in terms of providing learning opportunities, monitoring learning outcomes, reducing class sizes, balancing pupil-teacher ratios, improving quality of teacher training and ending scarcity of textbooks and resources.

It has been a decade since the launch of the INCF 2005 for school education in India. This framework recommends many reforms in the fields of curriculum, methods of instruction, assessment and teacher education, in the light of constructivist and other modern theories of learning. Predominantly, the INCF framework recommends adoption and implementation of learner-centred pedagogies in Indian classrooms and proposes to change prevailing traditional learning and teaching practices. Many reports such as *Teaching and Learning: Achieving Quality for All* by UNESCO (2014), and educationists such as Pritchett (2015) and Srivastava (2015) have criticised the INCF 2005 referring to it as ‘ambitious’, ‘overambitious’, subject-centred rather than student-centred, not aimed at promotion of analytical skills and independent learning skills, and not specific to the diverse Indian context. Although the INCF framework appears to be supporting teaching and learning through the learner-centred, active and participatory methods, the reality on the ground appears to be different from the recommendations, the impact and enactment of the INCF 2005 is rarely (and yet to be) seen in Indian secondary science classrooms (A. Padmanabhan, 2014; Srivastava, 2015). Therefore, the distinction proposed by Hume and Coll (2010) between the formal or *intended curriculum* and operational or *student-experienced curriculum* seems appropriate in the Indian context. In an actual sense this is a dilemma which needs to be resolved urgently to put the planning in practice. Nevertheless, the INCF recommends making science learning active, student-centered, relevant, interesting, and an enjoyable affair for Indian students. It is interesting to note that on one hand the *ambitious* INCF 2005 puts emphasis on the development of 21st century skills such as ICT, communication and collaboration, while on the other hand India can be seen occupying a place in the top bracket of 21 countries facing an *extensive* learning crisis (Srivastava, 2015). Moreover, the UNESCO (2014) report mentions the major factor behind the broad learning gap stating “India’s curriculum, which outpaces what pupils can realistically learn and achieve in the time given, is a factor in widening learning gaps” (p. 33).

This thesis is an attempt to implement and evaluate some of the recommendations of the INCF 2005 in relation to teaching and learning of secondary school science and to implement a learner-centred pedagogy in selected Indian secondary science classrooms. To be more specific, this study offers some solutions based on the design, enactment and evaluation of a teaching-learning intervention to enhance students’ science learning and motivation, and to narrow the prevalent learning gap in Indian secondary science classrooms.

1.2. The Indian Context

India is a diverse country of over 1.25 billion people residing in 29 states and 7 union territories[3] (UTs). The Indian constitution defines the legislative powers of the states and the centre governments into the three categories of lists: The *Union list*, the *State list* and the *Concurrent list*. Education was on the *State list* and was a state affair before 1976, but after that it was transferred to the *Concurrent list* and came under the direct control of the Centre Government. The main reason for this shift was to promote meaningful partnerships between the Centre and the State Governments (Kumar, 2012). The education sector is managed by the Ministry of Human Resource and Development (MHRD) of the Government of India (GoI). All major decisions about the planning, developing, implementing and evaluating of education initiatives are made by the MHRD. Under the MHRD, there are two departments of education: The Department of Higher Education (DHE) and the Department of School Education and Literacy (DSEL). The DSEL is divided into three divisions: elementary education, secondary education and adult education and literacy. These divisions are responsible for ensuring the smooth organisation of education at specific stages of schooling.

Access to good quality education is a fundamental right under different articles of the Indian Constitution. The Right of Children to Free and Compulsory Education Act (*RTE; Right to Education* in short) 2009 has made education free and compulsory for children between 6-14 years of age or up to class[4] 8 (Ministry of Law and Justice, 2009). The federal government has launched many schemes to enhance enrolment and universalize school education in India. Prominent among these schemes are the District Primary Education Program (DPEP), launched in 1985 for primary education; Sarv Shiksha

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[3] In India, the 29 states are governed by the respective state governments through the Chief Ministers and legislative assemblies whereas the seven Union Territories are governed by the central government through the appointed Governor. These UTs do not belong to and are not parts of any state.

[4] Class (e.g. VIII or 8th) in Indian schooling system is referred to as *grade* in the US or *year* in New Zealand. In the Indian 10+2 system of education there are 12 classes starting from class1 and ending with class12.

Abhiyaan[5] (SSA), launched in 2001 to universalize elementary education; and Rashtriya Madhyamik Shiksha Abhiyaan[6] (RMSA), launched in 2010. Through its federally sponsored scheme RMSA, the Indian Government is aiming to improve the quality of, and universalize secondary education (National Council of Educational Research and Training, 2009). Enhancement of enrolment rates, lowering of dropout rates and ensuring retention, strengthening of science and mathematics education, vocational education, inclusive education for disabled, marginalised and girls, promotion of ICT skills, enhancing quality of the teaching and learning material and promotion of collaborative and participatory pedagogy are some of the major objectives of the RMSA scheme.

Throughout the history of Indian school education, the enrolment, literacy, retention and dropout rates have dominated the educational debate (Planning Commission Government of India, 2013b). After Indian independence this debate started through the establishment of the Secondary Education Commission (SEC, 1952-53), the Indian Education Commission (IEC, 1964-66), the National Policy on Education (NPE, 1968) and the Indian National Curriculum Framework (INCF, 1975). In the second National Policy on Education (NPE, 1986), revised in 1992 through its *Program of Action* (PoA, 1992), the quality aspect of education was first discussed, however, the emphasis was again more on enrolment, literacy, dropouts and retention rates (National Council of Educational Research and Training, 2009; Planning Commission Government of India, 2008). After the success of different schemes to address these issues, and the recent confrontation with/revelation of the *extensive learning crisis* (see section 1.3), the Indian Government has focussed more seriously on the quality aspect (Banerji, 2012, 2014; Ramachandran, 2015) by defining it in operational terms such as defining minimum levels of learning achievement, description of learning outcomes, improvement of infrastructure and facilities, improvement of pedagogic processes, and monitoring and assessing the learning progress at different stages of schooling.

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[5] Sarv Shiksha Abhiyan (SSA), English translation 'Education for All Campaign', is a United Nations' funded scheme for the universalization of elementary education in India. It was launched in India in the year 2001.

[6] Rashtriya Madhyamik Shiksha Abhiyaan (RMSA): English translation 'National Secondary Education Campaign' is a scheme to universalize and improve secondary education in India.

Since 2001, the Indian Government has started conducting the National Achievement Surveys (NAS) periodically through its apex body National Council of Educational Research and Training (NCERT). However, it is only the recent surveys, for instance, *NAS Class VIII (Cycle 3) 2012* and *NAS Class V (Cycle 3) 2011* that have reported systematic, reliable and comprehensive data (National Council of Educational Research and Training, 2014b). There are other annual educational surveys (e.g. *ASER; Annual Status of Education Report*) conducted by *Pratham* a Non-Governmental Organisation (NGO) which began in 2005 and usually provide a differing picture of the achievement of Indian students than that provided by the government funded NAS. Many aspects such as methodology, sampling and measurements of these surveys have been frequently criticised by advocates of the two kinds of surveys (ASER, 2015). However, the common concern that both surveys highlight is the persisting learning crisis and decreasing learning levels both at primary and secondary stages of education (Pritchett, 2015).

1.2.1. School education in India

India has a diverse as well as complex school system. All the 29 states and 7 union territories (UTs) of India have adopted a uniform structure of school education viz. the 10+2 system of education. The first ten years of schooling is comprised of the elementary (grades 1-8) and secondary (grades 9-10) stages of education. Elementary education is further seen as comprising of five years of primary and three years of upper-primary education. The last two years of the schooling (grades 11-12) is called senior or higher secondary. Until the secondary stage of schooling most of the school subjects are compulsory (for example languages- regional and English, sciences- natural and social, and mathematics) and other subjects can be chosen as an elective or additional subject. All students have to sit the public examination at the end of grades 10 and 12 of secondary and senior secondary education. These examinations are conducted by the Central Board of Secondary Education (CBSE), the Council for the Indian School Certificate Examinations (CISCE), National Institute of Open Schooling (NIOS) and different state education boards. Sitting the public secondary education examination is made optional by some of the central and state boards following the *Yashpal Committee* report named *Learning without Burden* published in 1993. Under the 10+2 system of education, during the last two years of education most of the subjects are offered according to different streams, specialization or vocations.

The National Council of Educational Research and Training (NCERT) is the apex body responsible for the curriculum development, design of text-books, policies and different schemes of school education in India. The NCERT provides support and technical assistance to most of the schools in India. The council is comprised of constituent institutes, for example, the National Institute of Education, and the Central Institute of Educational Technology, which provide specialised support to the school system. Additional support to the NCERT on educational planning and management and teacher education is provided by the National University of Educational Planning and Management (NUEPA) and the National Council for Teacher Education (NCTE). Based on the evaluations of the old educational policies, commissions and curricular frameworks, and the felt need to reform the school curriculum framework, the NCERT released the new National Curriculum Framework (INCF) in 2005 with an intention to improve the condition of teaching and learning in Indian schools. The NCERT also constituted various *National Focus Groups* (NFGs) on teaching of different subjects such as the *NFG on Teaching of Science* to inform domain specific issues of content, pedagogy and assessment (National Council of Educational Research and Training, 2006, 2009). These NFGs along with the INCF 2005 provide guidelines for educators and leaders to make decisions about the planning of teaching and learning for the specific subject and effective implementation of the curriculum as a whole in the school.

Education in India is provided, funded and managed by the public sector (the central and state governments) as well as the private sector (private trusts and organisations). Therefore, depending upon the funding, there are central schools like Kendriya Vidyalaya Sangathan (KVSs), Navodya Vidyalaya Samiti (NVSs), government schools, government aided private schools and privately funded and managed schools throughout India. Approximately 80% of the schools are government schools (Government of India, 2009), which makes the Government the major education provider in the country. But due to the poor quality (A. Padmanabhan, 2014; Srivastava, 2015) of education in government schools 27% of children in India attend private schools for education (The World Bank, 2009).

1.2.2. The quality of education

The quality aspect of school education has been an important topic of discussions while planning and executing school education since the start of 21st century (Planning

Commission Government of India, 2003). The *Tenth Five Year Plan (2002-2007)* of the Government of India's Planning Commission for the first time strongly stressed improving the quality of education at primary, secondary and tertiary levels (Planning Commission Government of India, 2008). However, initially this emphasis was limited to infrastructure, physical facilities, for example provision of buildings, laboratories, libraries and books and sufficient teachers. Since 2001, the Indian Government through following its *Five Year Plan*s and the Ministry of Human Resource and Development's constituent Department of School Education and Literacy (DSEL) has consistently focussed on the improvement of quality of education at primary and secondary stages. The *11th Five Year Plan* document of the Planning Commission Government of India (2008) articulated that one of the goal of the plan is "*Improved Quality* to be defined in operational terms through clearly identified outcome indicators, viz. learning levels of students, teacher competence, classroom processes, teaching-learning materials etc." (p. 10; emphasis added).

After the success of Sarv Shiksha Abhiyan (SSA) in terms of achieving access and nearly universal enrolment at elementary stage (grades 1-8) of schooling, the next challenge before the Indian Education system is to universalize secondary education (Planning Commission Government of India, 2013b). In this process, access, equity, governance and quality of secondary education are the major concerns (Ministry of Information and Broadcasting Government of India, 2010; National Council of Educational Research and Training, 2009; Planning Commission Government of India, 2008). The Indian Government has launched various schemes to address these aspects of secondary education. Initiated in 2009, the Rashtriya Madhyamik Shiksha Abhiyaan (RMSA; English translation- National Secondary Education Campaign) is a major scheme devoted to universalise and improve quality of secondary education in India. The ambitious scheme RMSA of the GoI, aims to achieve the ambitious aims of 75 % gross enrolment ratio by 2015-16, universal access to secondary level education by 2017, and to enhance and universalise retention by 2020. In addition to the access and retention, the RMSA also aims to improve the quality of education imparted at secondary level by making all secondary schools conform to prescribed norms. In order to achieve the goal of universalization of quality secondary education, the Indian Government re-constituted the Central Advisory Board of Education (CABE) in 2004, and established the Secondary Education Group (SEG) in April 2010 and upgraded it to

Department of Secondary Education (DSE) in November 2010. In 2014, some other schemes such as *ICT in Schools* and *Vocational Education* have been integrated with the RMSA and renamed as *RMSA (Integrated)* under the supervision of the MHRD (refer to http://mhrd.gov.in/rmsa_integrated and http://www.rmsaindia.org/en/ for more details). The National Resource Group (NRG) of the MHRD meets twice a year to plan, monitor and assess the progress towards the achievement of RMSA objectives.

Since the launch of the RMSA scheme in 2010, the ‘quality’ aspect of education has been defined clearly to include different dimensions of quality, for example students’ learning outcomes (what students learn), governance of schools (how schools are run) and provisions to schools (providing the resources that schools need to improve) (MHRD Government of India, 2014b). This plan is named by the MHRD as *Quality Education through School Improvement*. The National Council of Educational Research and Training (2009) document: *Vision and multi-layer strategic guidelines for improvement of quality of secondary education* clearly describes the learning indicators in terms of curriculum, pedagogy, teachers, learners, school management, and assessment processes and recommends a focus on these indicators to enhance the quality of secondary education. Further, the NCERT (2014a) more recently published a document titled *Learning indicators and learning outcomes at the elementary stage* to explicitly describe the curricular expectations, pedagogical processes and learning indicators at the elementary stage in different curricular areas. Moreover, *The 12th Five Year Plan* document of the Planning Commission Government of India (2013b) also highlights the need to improve the learning outcomes of students through the framing of learning and curriculum objectives, design of good quality learning resources/materials, and development and application of innovative pedagogic processes and assessment frameworks.

The Right to Education (RTE 2009) Act of the Indian Constitution (GoI) has stressed that every child from 6-14 years of age should be provided with quality education and this should be accessible. The RTE 2009 along with schemes like RMSA and SSA make it mandatory to provide the best quality education in every aspect. Therefore, addressing the quality issue of secondary education in the Indian context at present appears to be the first and foremost priority, as suggested by UNESCO (2013). UNESCO (2013) stressed that enrolment alone is not enough and the quality issue needs to be addressed as a priority. Further, the strong emphasis placed on achieving quality secondary education in the very complex Indian education system/context suggests the need to declare it a National Mission like other critical missions of the country, such as *National Skill Development Mission, National Rural Health Mission* and the earlier education related *National Literacy Mission*.

1.2.3. Science education in India

From ancient times India has been ahead in the science field with many important achievements in astronomy, medicine, metallurgy, physics, chemistry, engineering and mathematics (Indian National Science Academy, 2001; Ranade, 2008). The report by the Indian National Science Academy- *Pursuit and promotion of science: The Indian experience*- provides a detailed historical account of the development of science, technology and mathematics fields starting from the earliest Indus Valley Civilisation through to the modern Indian society after independence. The INSA report asserts that the role of science has been of great importance to Indian people from prehistoric periods. However, the only Nobel Prize for science awarded to an Indian was in 1930 during the British rule. Dr Chandrasekhara Venkata Raman was awarded the Nobel Prize for his ground breaking research on scattering of light in Physics. His valuable research contribution, known as, the *Raman Effect* made a significant contribution to modern scientific research. Other Indians who studied in India but worked and lived overseas and received the science Nobel Prize are Dr Har Gobind Khorana, Dr Subramanian Chandrashekhar and Dr Venkatraman Ramakrishan in the fields of medicine, physics and chemistry respectively. Some other famous scientists such as S. N. Bose, Meghnath Saha, J. C. Bose, Homi J. Bhabha, Birbal Sahani, Vikram Sarabai, S S. Bhatnagar and Dr A.P.J. Abdul Kalam contributed to international research in science and paved the way to many Nobel Prizes (Chatterjee, 2012). Dr S. N. Bose, who collaborated with the world famous Albert Einstein to discover the ‘Bose–Einstein condensate’ state of matter was also credited with a new particle known as *boson* under his name. However, S. N. Bose himself did not receive the coveted prize but he introduced a new chapter in material science research on which many others still today are researching and receiving the popular highest prize for their contributions to development of science and humanity. In relation to the overall achievement of Indian scientists, the report *India as a Global Leader in Science* by the Science Advisory

Council to the Prime Minister (2010) cites examples of their overseas contributions and states that "Indian basic science has spawned new technologies- but not in India" (p. 8).

Since the start of the twentieth century, and especially after Indian independence in 1947, the Indian Government took various initiatives to develop, promote and reform science and technology education in the country. The establishment of the world reputed Indian Institute of Science (IISc), 23 Indian Institutes of Technology and 31 National Institutes of Technology (NITs) with an aim to promote science and technology education is an indication of the extensive emphasis placed on science and technology by the Government of India. Some other reputed institutes such as the Tata Institute of Fundamental Research (TIFR; established in 1945) and the National Institute of Advanced Studies (NIAS; established in 1988) were also established by an industrialist J.R.D Tata on request from famous Indian scientists. The Homi Bhabha Centre for Science Education (HBCSE; established in 1974), a constituent unit of the TIFR, and the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR; established in 1989 by the Department of Science and Technology of the GoI) are two important centres of science education and research whose aim is to promote quality of and research in science education in India. At the school stage, these centres are promoting science education by organising national and international level *Science Olympiads* and *Children's Science Congresses*. Moreover, on recent recommendations by the Scientific Advisory Council to the Prime Minister (SAC-PM) the National Institute of Science Education and Research (NISER) and seven Indian Institutes of Science Education and Research (IISERs) were established during 2006-2016 and started functioning with an intention to be the IITs of basic sciences (Ministry of Science and Technology GoI, 2008). These institutions have been established under The National Institutes of Technology (Amendment) Bill, 2010 of the GoI and have been declared as *Institutes of National Importance*[7] by an Act of parliament. These IISERs, along with the NISER, are committed to promote and apply scientific knowledge and to enhance the quality of science education. In addition to these institutes, the three academies of science: The National Academy of Sciences, India (established in 1930), Indian Academy of Sciences (established in 1934) and the Indian National Science

[7] Institute of National Importance (INI) is a status that is given to a public higher education institution in India by an act of parliament which serves as a pivotal player in developing highly skilled personnel within a specified field such as science, medical and business. In 2015 these were 74 in number.

Academy (established in 1935; known as the National Institute of Sciences of India until 1970) are also playing a key role in the promotion of science-related research and activities.

1.2.4. School science curriculum

At the school level the National Council of Educational Research and Training (NCERT) is responsible for advising on issues of curriculum, pedagogy and methods of assessment. The NCERT published the INCF in 2005 in consultation with international experts and based on the latest research in the areas of curriculum, pedagogy and assessment. The NCERT also instigated 21 national focus groups (NFGs) such as the *NFG on Teaching of Science* in 2006 to address the quality and curriculum content, principles, pedagogy and assessment of learning in different curricular areas. The INCF (National Council of Educational Research and Training, 2005) and the NFG on Teaching of Science (National Council of Educational Research and Training, 2006) describe the aims of school science education, the curriculum content, methods of teaching, and assessment techniques according to the levels of schooling. The INCF and the NCF on Teaching of Science provide the following guidelines about the nature of a school science curriculum:

Through primary school science "the child should be engaged in joyfully exploring the world around and harmonising with it" (National Council of Educational Research and Training, 2005, p. 48). The major aim at primary stage is to develop curiosity of the child through hands-on activities and to develop basic cognitive and psychomotor skills, and science specific language skills through observation, classification and communication (National Council of Educational Research and Training, 2006). At the primary school stage, the study of science is integrated with social sciences to present the subject as *Environmental Studies* with a special emphasis on health and the environment. The National Council of Educational Research and Training (2006) also suggests avoiding any type of formal assessment for young children at the primary stage of schooling.

At the upper-primary (elementary) stage, the main aim of the curriculum is to familiarize children with some of the common principles and applications of science through activities, models, discussion with peers, group activities, simple experiments and surveys, and based on their experiences and the environment. Another major aspect at this stage is to present the value aspect of science in relation to daily life and society as a whole (National Council of Educational Research and Training, 2005). The subject *Science* is renamed as *Science and Technology* to present the major dimensions of scientific and technological literacy. The INCF 2005 (National Council of Educational Research and Training, 2005) suggests the provision of continuous and comprehensive assessment to facilitate students' learning and discourages detention of any student until grade/class 8.

The science curriculum at the secondary stage in Indian schools is structured around six broad themes. These are: matter (nature and components), energy (force, work, sound and energy), motion (simple and rotatory), life, health, and natural resources. At secondary school stage the INCF 2005 and National Focus Group (NFG) on Teaching of Science (National Council of Educational Research and Training, 2006) have outlined the following methods of teaching science:

1. Emphasis on scientific methodology; the process rather than the content;
2. Stress comprehension and understanding not merely definitions and facts;
3. Inclusion of abstract concepts which are beyond direct experience;
4. Development of critical ability to evaluate the epistemological nature of facts;
5. Provide an integrated and disciplinary view of science;
6. Include meaningful, locally relevant and environment-based content; and
7. Stress systematic experimentation to test theories and principles of science and technology.

1.2.5. Methods of Instruction

The INCF 2005 and NFG on Teaching of Science 2006 outlines the problem of rote learning and invalid methods of assessment prevalent in Indian schools and examination boards. The INCF 2005, the National Council of Educational Research and Training (2009) and the MHRD Government of India (2014b) raise concern about the current pedagogic practices in Indian classrooms stating that rote learning and teacher-centred (teacher as transmitter of information/knowledge) methods dominate classroom instruction, and are preferred over other methods known in Indian context. Further, the INCF 2005 and NFG on Teaching of Science emphasise and recommend educational reforms through shifting from rote memorization to conceptual understanding, promoting a spirit of inquiry and adopting innovative assessment techniques. Along with the above mentioned documents, the new National Policy of Education (MHRD Government of India, 2016) also stresses the need to make science education locally relevant, meaningful and an enjoyable experience for Indian secondary school students. A report by the Planning Commission of the Government of India (2013b) describes pedagogy as a key determinant for achieving the specified learning outcomes and stress the need to address the issue of pedagogy on priority basis. Therefore, this report endorses the introduction of some innovative and participatory pedagogies to improve the quality of learning at secondary school stage.

1.3. Rationale of the study

In the recent past, India has made remarkable progress in the enrolment, retention of students in school, and the universalization of elementary education (Ministry of Information and Broadcasting Government of India, 2010; Planning Commission Government of India, 2008). However, despite the launch of various schemes to improve education at school level and the extensive focus on science and technology by the Indian Government (as presented in the preceding section), the learning outcomes of students in science, mathematics, and languages are not satisfactory (ASER, 2011, 2015; Bhattacharjea, Wadhwa, & Banerji, 2011; UNESCO, 2014) and are of serious concern (Planning Commission Government of India, 2013b). According to the Planning Commission of Government of India reports (2008, 2013), nearly 50% of students fail in Science, Mathematics and English subjects at the elementary level. There is a very minimal amount of research/reliable data about the learning outcomes of Indian secondary students (The World Bank, 2009) and information presented by the ministries and their departments (such as DSEL) appears to be politically framed and/or motivated. There exists a wide difference between these government findings and independent/NGO observations.

The learning outcomes of Indian students are either not recorded or ill-recorded both at national and international levels (Kingdon, 2007). At the international level there is no information available about the learning achievement of Indian students because India participates in neither the Programme for International Student Assessment (PISA) nor in the Trends in International Mathematics and Science Study (TIMSS) surveys. In their *debut* and trial appearance in the PISA 2009 survey (M. Walker, 2011; PISA Plus results published by ACER, Australia) Indian students just managed to finish second (73rd rank out of 74 countries) from the bottom, leaving only Kyrgyzstan students behind them. In this only international assessment about 87% of Indian students were placed at and below level 1 of scientific literacy[8] and around 13% attained the mid-range levels[9] of 2, 3 and 4. This performance appears no less than a mockery of Indian science education (Kaushik, 2015).

At the national level, a major factor for the poor record of results of learning achievement is the meaningless comparison of the results of more than 40 examination boards across India. Schools affiliated with these boards differ in curriculum content, methods of teaching and types of assessments (ASER, 2015; UNESCO, 2014), thus comparison is virtually meaningless. The National Council of Educational Research and Training (NCERT), since 2001, has been presenting the learning outcomes of Indian students through the National Achievement Surveys (NAS) for grades 3, 5 and 8. However, the survey findings have been reported as being not reliable and comprehensive (ASER, 2015). The achievement results of elementary students from the National Achievement Survey conducted by NCERT in the year 2005 are given in Table 1.1. Similar findings have also been reported by the Annual Status of Education Report (ASER) surveys since 2005.

Analyses of results in Table 1.1 indicate that achievement in science is less than satisfactory and declining as a student progresses to more senior grades. Recognizing these results and the need to improve the learning outcomes of students at elementary and secondary stages of school, NCERT, the apex body to decide the curriculum and direct policy in India, stresses the need for making learning joyful and permanent (especially in science and mathematics) through the INCF 2005 and National Focus Group on Teaching of Science (National Council of Educational Research and Training, 2005, 2006).

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[8] According to PISA, scientific literacy is, "An individual's scientific knowledge and use of that knowledge to identify questions, to acquire new knowledge, to explain scientific phenomena, and to draw evidence-based conclusions about science-related issues, understanding of the characteristic features of science as a form of human knowledge and enquiry, awareness of how science and technology shape our material, intellectual, and cultural environments, and willingness to engage in science-related issues, and with the ideas of science, as a reflective citizen" (M. Walker, 2011, p. 52)

[9] Levels of scientific literacy are decided on the basis of students' knowledge and ability to perform most basic tasks (level 1) and solve advanced problems (level 6) on PISA assessment.

Table 1-1 *Learning achievement at Elementary level*

Stages of education (at the end of)	EVS (for grades 3 & 5) /Science (for grade 6 onwards)	Mathematics	Languages	Social Science
Grade 3	-	58.25	63.12	-
Grade 5	50.3*	46.51	58.57	-
Grade 7	35.98	29.87	53.0	32.96
Grade 8	40.54	38.47	52.45	45.0

Source: Planning Commission Government of India (2008)
* The data are reported as percentages

The motivational facet of the rationale has two aspects: the high dropout rates of secondary students because of poor performance at earlier grades and the declining interest of Indian secondary students to learn science in higher grades. The *Educational Statistics at a Glance* (MHRD Government of India, 2014a) report states that the gross enrolment ratio (GER) of Indian students at secondary level (grades 9-10) and at senior secondary level (grades 11-12) are 73.6 and 49.1 respectively (with a joint GER of 62.0% for 9-12 grades). The *8th All India School Education Survey* published by the NCERT (2016) however, reports the secondary education GER as 54.55, whereas, a World Bank (2009) study reports it as 40% for grades 9-12, which is less than half of the average of its South and East Asian counterparts (The World Bank, 2009). Moreover, the drop-out rate at the upper-primary (grades 1-8) and secondary (grades 1-10) stages are 36.3% and 47.4% respectively (MHRD Government of India, 2014a). Pandita (2015) expresses his worry about the massive dropout rates of Indian students and reports that 58.80% students drop out by the time they reach elementary level and 79.95% drop out by the secondary level. One of the major reasons for the massive dropout rates at the secondary (after upper primary) level of schooling is students' poor performance in science and mathematics subjects (Pandita, 2015; Sarangapani, 2014; Shukla, 2005) at the upper-primary and elementary level. Because of the failures in science and maths the pass percentage of students at secondary level is 52.1% and out of these pass out students, those who choose to study science after secondary school, only 37.5% students manage to pass at the senior secondary exam (MHRD Government of India, 2014a). Similar reasons for the lack of retention are mentioned by international researchers. For example, Rumberger (2011) in his book *Dropping Out* states that "research shows that poor academic performance in middle school and even elementary school can decrease a student's motivation in high school, which can lead to failing courses and skipping school, the more immediate precursors to dropping out" (p. 15). These alarming and high dropout rates are crucial challenges for the Indian schooling system if it is to achieve the ambitious goals of 75% GER by 2017 and universal enrolment and retention by 2022 as envisioned by the RMSA (Planning Commission Government of India, 2013b).

Since the start of 21st century, there has been a constant decline in the interest and attitude towards science of Indian secondary students (Awan, Sarwar, Naz, & Noreen, 2011; Josphine, 2008; Laad, 2011; Schreiner & Sjøberg, 2007). By the time students reach secondary level, they have not maintained their interest and achievement in science and mathematics (Josphine, 2008; Laad, 2011). Some authors such as Padmanaban (2008) and Shukla (2005), however, report that there is no decline of interest at the upper-primary stage of schooling but it slightly declines in secondary and senior secondary grades. As a result of the decline in interest, there has been a decline in science enrolments after secondary education (Garg & Gupta, 2003; Jayaraman, 2007) resulting in only 12% of the total enrolled senior secondary students choosing to study basic science (MHRD Government of India, 2013). Reflecting on this declining interest of Indian students, the former prime minister of India has commented that he was "deeply concerned" about basic science enrolments (Jayaraman, 2007, p. 134) and therefore urged the scientific community to promote science among Indian schools and colleges. Keeping in mind the dropout rates at the senior secondary level due to poor achievement in science and declining enrolments, interest and attitudes, it seems urgent to motivate secondary school students to learn science to ensure the vision of the Science Advisory Council to the Indian Prime Minister (2010) of *India as Global Leader in Science by 2030* is achieved and in a timely manner. Keeping in sight the current situation and the action needed to achieve this aim, it appears that there is crucial need not only to engage secondary school students but also to motivate them to learn science - hence is the rationale of the current study.

1.4. Statement of problem

The problems of the quality of learning, including low and declining learning outcomes of Indian students, are evident from national as well as international reports. The quality aspect of learning includes pedagogic practices (teaching-learning methods), better methods of assessment to make students' learning visible, and monitoring of students' learning progress. The problem of declining interest in and attitudes towards science is another challenge that the Indian schooling system is facing. As a result, very few students opt for basic science subjects after the secondary stage of schooling. The 12th Five Year Plan document of the Planning Commission Government of India (2013a) stresses that education quality and learning outcomes must be improved and suggests the need for more research related to curricular and pedagogic process aspects, with special reference to science and mathematics subjects.

1.5. Objectives of the study

This research aims to:

1. Design an effective teaching-learning intervention to enhance students' conceptual learning and motivation towards science learning
2. Investigate the effectiveness of computer-based collaborative concept mapping (CCCM) in/for improving conceptual learning and motivation towards science learning
3. Examine science achievement of Indian secondary school students
4. Explore students' levels of conceptual understanding in science
5. Study the motivational orientations of Indian secondary students in relation to science learning
6. Prepare some sample concept maps, and train teachers and students to construct concept maps on different science concepts
7. Examine students' individual and group science learning
8. Study students' and teachers' perceptions of CCCM use in their classrooms
9. Study students' and teachers' perceptions of the barriers in and enablers for the CCCM use in the classroom

1.6. Significance of the study

Teaching of school level science for understanding and meaningful learning are well recognized as universal needs (Mintzes, Wandersee, & Novak, 2000, 2005). Educational researchers have been constantly trying to develop effective methods for the teaching and learning of science. Many countries are making efforts to make science learning an interesting and enjoyable experience through various schemes and policies. The USA, for example, recently launched two major schemes to enrich science education namely *Taking Science to Schools* in 2007 and *Learning Science in Informal Environments* in 2009. The Indian secondary school curriculum (*INCF 2005*) also recognizes the importance of quality and meaningful learning to make the process of education a joyful experience for students (National Council of Educational Research and Training, 2005). The Department of School Education and Literacy (DSEL) launched a scheme named *Quality Improvement in Schools* during the 10th Five Year Plan (2002-2007) of the Government of India. In this plan two existing schemes for enriching science education namely *Improvement of Science Education in Schools* and *International Science Olympiads* along with three other schemes were converged (Planning Commission Government of India, 2008). The INCF has recommended the use of contemporary learner-centred, socio-cultural, collective and interactive methods of teaching and learning for the improvement of secondary education (National Council of Educational Research and Training, 2005, 2009). The current study is expected to make a contribution towards the improvement of learning outcomes of Indian secondary school students by designing of an intervention and applying learner-centred, interactive and collaborative methods of learning. This study also intends to offer an instrument to assess and monitor students' science learning.

Research evidence suggests that in some school subjects like Science and Mathematics, there is a risk of generating and reinforcing misconceptions in students' minds. For example, Baxter (1989) and Trumper (2001) explored secondary school students' understandings of some familiar astronomical events (such as the motion of earth, sun and moon; formation of day and night; and change of seasons) and found that most of the students held misconceptions about these concepts. Another study by Duit (2007) compiled a bibliography of over 7000 studies on misconceptions in science. The STEM subjects seem to require higher cognitive skills and specific strategies to make the concepts clear and to achieve meaningful learning. Meaningful learning here refers to the ability of an individual to make sense and draw meanings from the information, in the same way as intended by the disseminator of the information or through negotiation of meaning-making in collaborative learning. According to the INCF 2005, "learning is active and social in its character" (National Council of Educational Research and Training, 2005, p. 13) and meaningful learning is not mere storage and retrieval of information, but a process of active representation and manipulation of concrete concepts in a knowledge domain. Meaningful learning can be enhanced by addressing misconceptions (C. W. Anderson, 2003; Ausubel, 2000; Mintzes et al., 2005). This research will explore and address some of the misconceptions in the process of science learning and assessment.

It is also hoped that this study will add new knowledge to the field of teaching-learning-assessment of science education, and generate interest and positive attitudes towards science among secondary students. The research will help secondary school students in acquiring knowledge and skills needed in their life and their future careers. Brophy (2010b) asserts that a motivated learner performs well in learning. The motivation to learn can be enhanced by teaching methods that actively engage students in learning (Keraro, Wachanga, & Orora, 2007). The INCF (2005) and the World Bank (2009) emphasise shifting from rote learning methods to conceptual understanding via an integrated approach to learning and teaching and improving the quality of secondary education in India. Therefore, it becomes imperative to devise innovative and effective methods and strategies of teaching and learning to improve the quality of secondary science education based on recent theories of effective pedagogy and research evidence worldwide. The Planning Commission Government of India (2013b) report also indicates that more research is needed to investigate the effectiveness of different pedagogical methods and strategies to improve learning outcomes of students. This study will investigate the effectiveness of one such strategy on effective, active and meaningful learning of science and on motivation towards science learning of Indian secondary school students to reduce the learning crisis. By doing so, this research will contribute to the realisation of the vision: *India as a global leader in science by 2030* (Science Advisory Council to the Prime Minister, 2010) by motivating Indian secondary school students to learn science.

1.7. Structure of the thesis

Chapter one has described the research problem that this study addresses along with an explanation of the Indian school and science education contexts, the research aims and rationale, and outlined the significance of the research. Chapter two presents the review of relevant literature. In the beginning of chapter two, some learning and motivation frameworks are described to situate the study and to operationalize the concepts of learning and motivation. The concept, process and strategies of meaningful learning are discussed after that. Later sections provide an overview of some of the already available interventions in science education. The need for the present motivation-oriented intervention is argued and then the actual process of its design is described. The research questions and hypotheses of the study are presented at the end of chapter two.

Chapter three provides the selection and rationale of the Design-based Research Methodology (DBR) for this study. An overview of some of the popular paradigms is provided to situate the study in a specific worldview, and philosophical aspects (ontological, epistemological and methodological) are discussed. The meaning, definition and process of the DBR are presented. The research design and procedures applied to carry out this study are discussed after that. A description of the research instruments designed and used is provided and the procedures for data collection and analysis are explained. Finally, the ethical principles are explained and considered in relation to this study.

Chapter four presents the quantitative and qualitative findings in relation to the effect of the intervention on students' conceptual learning, science achievement and motivation towards science learning. Students' conceptual learning is analysed and a comparison of individual and the group learning (concept maps) is presented. After that, results for the motivation construct are presented. The teacher interview and students' group discussion results are presented to report teachers' and students' perceptions and experiences of the intervention use. To end the chapter, some barriers and enablers to the CCCM use in the classroom as perceived by students and teachers are also reported.

Chapter five provides a discussion of the findings in light of the relevant literature. The discussion is presented according to the research questions of the study. The quantitative results in relation to the science achievement and conceptual learning are discussed at the beginning of the chapter. Then the results obtained for students' motivation towards science learning are discussed. This is followed by a presentation of teachers' and students' views about the use of CCCM in their classrooms. Finally, some enablers for and barriers to the CCCM use are discussed.

The final chapter six of the study provides conclusions of the research and implications for the teaching and learning of science in the Indian and international contexts. The limitations of the study are discussed and recommendations for further research are presented in the light of the findings and limitations of the study. At the end, a framework for motivating secondary students to learn science is proposed in relation to study's contribution to the field of science education.

Chapter Two. Literature Review

This chapter presents a discussion of the literature in relation to the learning and motivation constructs, and around the research objectives of the study. Initially, the theoretical frameworks which guided both the design of the learning intervention and the conceptual framework of the study are presented. Some of the major theories of learning and motivation are analysed and discussed. After that, the concepts of motivation to learn and meaningful learning are discussed. This is followed by the description of some strategies and interventions to enhance conceptual learning and motivation to learn. The design of the intervention used in the study is then described and its need in the Indian context is argued. This is followed by the conceptual framework of the research. Finally, the research questions and hypotheses of the study are outlined.

2.1. Learning frameworks

This section begins with a discussion of some of the definitions of learning and an operational definition of learning for the study is presented afterwards. Some major learning frameworks are analysed and discussed. The purpose of presenting different learning frameworks is to adapt and use the most suitable to the current research. A similar process is followed for the *motivation* construct in section 2.2. The relationship between learning and motivation is established in section 2.3.

2.1.1. Learning defined

From time to time, many researchers of education have tried to define learning. However, as a result of the differing objectives, foci, intended outcomes, processes and methods, many different definitions of learning exist. Schunk (2012) defines learning as "an enduring change in behaviour, or in the capacity to behave in a given fashion, which results from practice or other forms of experience" (p. 3). This definition simply explains the process of learning in terms of its products, although the continuing aspect of change is outlined. This definition also suggests that the processes involved in learning cannot be observed directly while it is in progress. Rather, learning can be assessed from the outcomes in terms of changed or modified behaviours. The three main aspects which Schunk's definition touches on are the *changing* nature (of behaviour) *over time* and the occurrence of this change through practice or other forms of *experience*, for example, language learning in social settings, and learning of different behaviours by imitating and observing others.

According to Woolfolk (2014), "**learning** occurs when experience (including practice) causes a relatively permanent change in an individual's knowledge or behaviour" (p. 272; emphasis in original). Woolfolk suggests that this change may be conscious or unconscious, correct or incorrect, and unintentional or well planned. This definition suggests that learning is change in an individual's knowledge or behaviour. One of the aspects of this definition, consistent with a cognitive perspective, suggests learning can be seen as a change in knowledge, which is an individual's internal cognitive activity that cannot be observed directly. Whereas another aspect, which seems congruent with the behavioural and social-cultural aspects, suggests that the change in a person's behaviour is caused by external elements (Woolfolk, 2014). From this view, learning can be understood as a function of the environment, interactions and relationships in the society.

UNESCO (2013) defines learning as:

> The process by which people acquire knowledge, skills and attitudes. 'Quality learning' encompasses processes through which people acquire the breadth and depth of knowledge, skills and attitudes necessary to fully engage in their communities, express their ideas and talents and contribute positively to their societies. (p. 1; emphasis original)

This UNESCO report describes the quality dimension of learning and establishes a strong association between the quality of learning and employment, economical and democratic stability and good citizenship. The UNESCO report further recommends focusing on the development of critical thinking, higher-order cognitive skills and fostering lifelong learning in addition to the development of the basic life skills of literacy and numeracy.

Alexander, Schallert and Reynolds (2009) use a metaphor of a river system to describe the changing nature of learning. The authors compare the concept of learning with the river system to represent the dynamic nature of learning- its interactional nature, learner characteristics, and the contexts and situations in which learning occurs. Alexander et al. (2009) conclude that learning, like the river system, is in a continual flux. This dynamic nature of learning has developed a new ‘science of learning’ (National Research Council, 2000a; Sawyer, 2014a) starting from a simple concept. Learning has established itself as a science because it has its own schools of thought, scientific basis, theories, perspectives, views, principles, strategies and methodologies (Sawyer, 2014a). Now, there are almost as many views on learning as number of researchers in the field. Therefore, it seems difficult to define the concept of learning precisely; rather, precision has become a relative term depending upon the philosophy of the proponent of the definition and concept.

Alexander et al. (2009) propose a very comprehensive definition (labelled by the authors as a working definition) of learning, describing it in terms of the four dimensions: what, where, who and when of learning:

> Learning is a multidimensional process that results in a relatively enduring change in a person or persons, and consequently how that person or persons will perceive the world and reciprocally respond to its affordances physically, psychologically, and socially. The process of learning has as its foundation the systemic, dynamic, and interactive relations between the nature of the learner and the object of the learning as ecologically situated in a given time and place as well as over time. (p. 186)

Alexander et al. (2009) advance a framework to position the theoretical perspectives and empirical investigations of learning and describe the learning construct, keeping in mind its changing, situated, process-product and interactional aspects. The Major characteristics of learning that Alexander et al. (2009) report are change, inevitable, essential, ubiquitous, interactional, process and product, different at different times, and can be tacit and incidental as well as conscious and intentional. Another study by Arthur Graesser (2009) compiled 25 principles of learning, most of them related to cognitive aspects of learning, and also recommend the inclusion of motivational, emotional, discourse, social interaction, personality, development and neuroscience aspects in addition to cognitive aspects.

Therefore, due to the impact of the above mentioned aspects, it is difficult to define learning in a sentence or two, as it keeps changing according to the focus, content, and context. Moreover, the continuously changing nature of learning environments and situations has also added to the increasingly complex nature of learning. However, the good thing is that much is presently known about the learning process, as the field of learning has established as an evolving science (P. A. Alexander et al., 2009; Collins, Joseph, & Bielaczyc, 2004; National Research Council, 2000a), generally referred to as *learning sciences* (Sawyer, 2014a). Furthermore, a comprehensive image of how people learn is evolving because of the constantly developing methods of enquiry, collaborations between researchers and practitioners, and the increasing interdisciplinary nature of education (St. George & Sewell, 2014).

2.1.2. An operational definition of learning

Consistent with the aims and focus of this research, learning is defined in this study as the process of development of cognitive, social, emotional, communication and ICT skills, and positive attitudes towards the acquisition of scientific knowledge of the science concepts, all of which result from collaborative educational dialogues, talk and argumentation. The specific focus in this study is on the development of lower-order cognitive skills (LOCS) and higher-order cognitive skills (HOCS), because both play important roles in understanding of concrete and abstract science concepts. Another major focus, which the second part of the definition stresses, is the role of motivation in preparing students for understanding science concepts, which is explored in the following sections.

From a conceptual learning point of view, learning can also be defined as the acquisition of abstract scientific knowledge, and understanding of different science concepts in relation to a specific phenomenon or a topic. Understanding of science concepts and their relationships to phenomena can be measured by assessing different kinds of knowledge: factual, conceptual, conditional, meta-cognitive and procedural, the cognitive skills (LOCS and HOCS) and the concept maps constructed by students. In relation to motivation to learn science, as discussed in section 2.4, a students' predisposition to understand the science content is the main focus in this study.

2.1.3. Learning frameworks

The concept and process of learning has been of interest to philosophers, psychologists, educators, educationists and researchers for many years (St. George & Sewell, 2014). From time to time learning has been defined according to a particular focus, content and the setting. As a result of the differences in the foci, contents and contexts, however, the meaning and definition of learning has been changing. These changing views about the meaning of learning, starting from the earliest views to the major recent views, are presented in the following sub-sections.

2.1.3.1. Learning as acquiring responses

The Behavioural theories of learning which can be traced back as far as Aristotle defined learning in terms of the association between the stimulus and the response (Vousden, Wood, & Holliman, 2014). The *Classical Conditioning* theory of Pavlov and the *Operant Conditioning* theories of Skinner and Thorndike defined learning as "relatively permanent change of behaviour as a result of experience with, and feedback from, the environment" (Vousden et al., 2014, p. 43). These theories were mostly based on laboratory studies of different animals and they explained learning as a result of the acquisition of responses by providing different conditions and types of stimuli in the environment. The intensity (strength and weakness) and frequency of responses could be varied according to desirable and undesirable behaviour. Therefore, these theories were also referred to as *behaviour modification* theories and *conditioning theories* (Schunk, 2009). According to Schunk (2009) the conditioning theories do not explicitly address memory and other internal processes to explain acquisition, shaping and change of behaviour. Behavioural theories of learning considered learners as passive recipients of information and teachers as creators of conditions to elicit certain kinds of responses by breaking down learning into small steps (St. George & Bourke, 2008; St. George & Sewell, 2014).

Behavioural theories of learning have been and continue to influence the practice of teaching and learning by offering important laws and principles of learning (Slavin, 2012). The principles, for example laws of practice, reinforcement, rewards and punishments, played important roles in explaining and understanding much of human behaviour. For pedagogy, these principles and laws guided the process of development of instructional objectives and planning of programmed instruction to achieve important and desired learning outcomes (Schunk, 2009).

2.1.3.2. Learning as acquiring knowledge

In response to relatively less emphasis put on the cognitive processes by behavioural theories, the cognitive theories stressed the importance of active knowledge processing. These theories shifted the focus from acquisition of responses to the acquisition of knowledge by active processing of the information transmitted by the teacher (St. George & Sewell, 2014). Major among the cognitive theories are Piaget's theory of cognitive development and James Bruner's and David Ausubel's cognitive learning theories. These theories go beyond behaviours and focus on understanding the cognitive procedures involved in the processing and remembering of information (Vousden et al., 2014; Woolfolk, 2014). Woolfolk (2014) notes that these theories outlined and explained the role of the short-term, long-term and working memories, perception, attention, forgetting, representation and storage of knowledge and the working of the cognitive systems involved in all of these processes. The acquisition of new knowledge was seen as dependent on the already existing knowledge of the learner, because it could play an important role in determining the extent of the learners' attention, perception, remembering and forgetting of information (Sawyer, 2006).

In relation to classroom practice, the knowledge acquisition view has played an important role in learning domain-specific skills, knowledge and attitudes. In science and other domains these theories are very helpful in learning abstract concepts and their relationships. The classroom teacher is expected to organise and represent the information for the purpose of enhancing students' knowledge and ensuring the accuracy of the knowledge (St. George & Sewell, 2014). Although the knowledge acquisition view of learning stressed the importance of cognition and information processes to some extent, it tended to promote rote memorisation and factual, surface and procedural knowledge, but not deep conceptual knowledge and understanding. The student was still seen as the recipient of the information and teacher played the dominant role in the classroom (Slavin, 2012; Woolfolk, 2014).

2.1.3.3. Learning as constructing knowledge

The knowledge construction view of learning outlined in constructivist theories considers learners as active builders of knowledge. A basic assumption of the constructivist theory of learning is that learners construct new knowledge based on their prior knowledge, beliefs, cognitions, experiences and with many possible interactions in their environment (Schunk, 2009; Slavin, 2012; Woolfolk, 2014). Slavin (2012) traces the historical roots of constructivist theories to the works of Dewey, Piaget and Vygotsky. John Dewey considered the process of education (learning) primarily social rather than as individual development of knowledge (Dewey, 2004; Hildebrand, 2008). Slavin (2012) states that the contemporary constructivist views, for instance sociocultural views, are heavily influenced by the work of Vygotsky. Vygotsky emphasised the important role played by the social interactions and relationships in the process of learning. Vygotsky's conceptions of the social nature of learning and the concept of *zone of proximal development* (ZPD) are especially crucial to understand the nature of knowledge individuals construct in a social situation. Recent concepts and methods of learning, such as *cognitive apprenticeship*, *thinking together*, and *learning togethe*r, are direct results of social constructivist theories. Other more specific strategies of learning based on constructivist and social constructivist perspectives include co-operative learning, the *Know-Want-Learn* (K-W-L) technique (Ogle, 1986), problem solving, discovery learning, reciprocal teaching, group investigation and the *Peer-Assisted Learning Strategies* (PALS). While describing the instructional implications of constructivist theories, St. George and Sewell (2014) state that students learn many skills, values, attitudes and behaviours in addition to the curriculum content when they are involved in social situations of the classroom.

Simpson (2002) argues that constructivism is not a theory of learning; rather Simpson considers it an epistemology and a philosophical orientation and warns constructivist followers to be aware of mixing the meanings of epistemology with the practice of instruction. Simpson (2002) further states that there are many instructional models and strategies available based on the recently popularised term 'constructivism' which differ according to the nature of content and different domains, and argues that there is not a solitary strategy that is able to achieve success with all students. Woolfolk (2014) also notes that there is no single *specific* theory of constructivism but most constructivist theories of learning emphasise two main ideas. First, learners usually are active and engaged in the process of learning and second, social interactions play an important role in the knowledge construction process. Subsequently, many popular educational texts such as Woolfolk (2014) and Good and Brophy (2008) report two different kinds of constructivism: individual/cognitive/radical constructivism and social constructivism. The two types of constructivist theories share most of the underlying assumptions of constructivism. The major difference between the two is the individual cognition and experiences are the focus in the former, whereas, all the individual cognitive processes are believed to originate from social interactions according to the latter. Further discussion about constructivism in the field of science education and in relation to this study is presented in section 2.1.4.

2.1.3.4. Learning as participating in shared activities

The participatory view of learning emerged as a result of the explicit emphasis placed on the social and situated nature of learning (St. George & Sewell, 2014) and thus can be viewed as an extended view of social constructivism. Dewey proposed that children learn best through democratic participation in the community (Hildebrand, 2008). According to St. George and Sewell (2014), the concepts of *Intersubjectivity* and *ZPD* of the sociocultural theory of Vygotsky also played an important role in the development of the participatory view of learning. Intersubjectivity, which is also known as shared consciousness, suggests that thinking and learning initially originate from, and take place on, the social plane between individuals and then within the individual (Vousden et al., 2014). This view of learning defines learning as a result of doing things with others in a community (Watkins, 2003) and describes the process of knowledge building in a community of learners. From the sociocultural perspective both students and teachers assume active and responsible roles in the process of shared construction of knowledge in a social context (Woolfolk, 2014). The community can consist of experts, teachers, researchers and students, who co-construct and share meanings in joint and shared activities. The sociocultural view of learning also puts emphasis on the *funds of knowledge* which learners bring to the learning situation and that are mostly drawn from individual experiences and cultural beliefs. These funds of knowledge play an important role in making connections (Sinnema & Aitken, 2012) between prior and new knowledge; promoting discussions and dialogues (Roth, 2005) and ultimately analysing and achieving the true nature of learning. Sociocultural approaches to learning benefit from the integration of different expertise, experiences and beliefs in the process of learning of professional skills and knowledge (St. George & Sewell, 2014).

2.1.3.5. *Learning as creating new knowledge*

Paavola and Hakkarainen (2005) proposed the need to consider an additional framework of learning that would encompass the emerging modern, networked, complex and knowledge-based societies, addressing "all the cognitive, social, and motivational challenges" (p. 548) by developing specific and effective instructional artefacts. Paavola and Hakkarainen name this the *knowledge-creation metaphor* and state that it developed as a result of the development of the *new science of learning* (Sawyer, 2006) and its related fields such as Computer-Supported Collaborative Learning (CSCL). The knowledge creation metaphor integrates basic elements of both the knowledge acquisition and participation metaphors but essentially differs on the focus and scope of the nature and dimensions of knowledge (Paavola & Hakkarainen, 2005). The major focus according to this metaphor is on the deliberate advancement of knowledge and innovation (St. George & Sewell, 2014) to transform education.

In relation to classroom implications of the knowledge creation view, Paavola and Hakkarainen (2005) proposed the *progressive inquiry* model of learning (see Paavola, Lipponen, & Hakkarainen, 2004). This model emphasizes the important role of understanding the social and collaborative aspects in the process of knowledge building. The main purpose of the progressive inquiry model is to apply the knowledge creation approach in learning with an objective to develop new methods of instruction and to advance knowledge in the community. Learners working towards the creation of new knowledge learn many new ways of collaborating with others and develop complex skills, competencies and attitudes (St. George & Sewell, 2014). Therefore, Paavola and Hakkarainen (2005) recommend restructuring educational practices aligned with the new approach to develop individual and collective competence for knowledge creation to solve increasingly complex problems (St. George & Sewell, 2014).

2.1.3.6. *Complexity in choosing a suitable framework*

In addition to the above mentioned frameworks/views of learning, some additional and recently developed frameworks are also relevant. These include: learning as problem solving, learning as thinking skills, learning as biochemical activity in the brain, learning as conceptual change, learning as social negotiation, learning as contextual change and learning as an activity (Jonassen, Marra, Howland, & Crismond, 2008).

From time to time, researchers such as Sfard (1998) have warned practitioners not to fall into the trap of believing and choosing just one view of learning. Sfard (1998) describes the acquisition metaphor as a process of acquisition of something, the learner as the recipient and the teacher as the provider or mediator. The ultimate goal of the knowledge acquisition metaphor is the enrichment of an individual through the possession of the knowledge or concept as a commodity (Sfard, 1998). The knowledge acquisition metaphor is a combination of the information processing and the cognitive constructivist perspectives (St. George & Sewell, 2014). The participation metaphor of learning, according to Sfard (1998), perceives the learner as a participant (intern) and the teacher as an experienced and expert participant in the process of community building through discourse and dialogue. After describing and analysing both the metaphors of learning, Sfard concludes that neither of the metaphors is adequate, but both are important for understanding learning. Both can be integrated and used to develop a comprehensive understanding of the process of learning. The selection and integration thus depend on the main goal of the activity and the nature of the content of the domain. The new metaphor, knowledge creation, stresses that in addition to the learning of domain-specific content, learning should also emphasize knowledge creation in terms of development of skills, competencies and attitudes needed to advance and apply knowledge in the field (St. George & Sewell, 2014).

2.1.4. A suitable learning framework for the study

Having reviewed most of the major learning frameworks, it appears that the process of learning is complex. The complexity further increases when it comes to the field of science education. Given the highly objective nature of scientific content/knowledge, one has to be extra careful in choosing appropriate learning frameworks and/or while integrating different frameworks to adapt a suitable framework for the research. In the field of science education, almost every framework seems suitable, at one time or another, to explain learning of different and complex scientific content. Several researchers, such as Taber (2010, 2011a, 2011b), Osborne (2015, 2007) and Simpson (2002) have criticised the epistemology of constructivism in relation to science teaching and learning. The common argument which all the critiques provide against constructivism in science education is the problem of epistemological relativism, which proposes that knowledge is relative to time, place, society, culture, conceptual framework and personal beliefs. Most of these researchers appear to agree with the individual/cognitive type of constructivism but when it comes to the social construction of knowledge they seem to take the position that scientific knowledge, being based on scientific laws and models, cannot be relative and constructed by non-experts, rather it is discovered by scientific communities (Osborne, 2007, 2011, 2015; Simpson, 2002; Taber, 2006, 2011a, 2011b). However, many science educattors seem to promote the use of constructivist methods of teaching and learning, but only after undergoing careful and rigorous design and selection (C. H. Liu & Matthews, 2005; Simpson, 2002). Some science education researchers (such as Linn, 2006; Littleton & Howe, 2010; Littleton & Mercer, 2013; Mercer & Littleton, 2007) have extensively used and promote teaching and learning strategies based on constructivist theories with an intention to enhance science learning and achievement. After all, the process of design and implemention of instructional methods depends on the broader educational goals, the nature of the subject matter and the specific context (Duffy & Cunningham, 2004; Palincsar, 1998; Simpson, 2002; Taber, 2006). Slavin (2012) suggests that as an epistemology, constructivism is compatible with the existentialism and pragmatism philosophies. Given the major goals of designing an intervention, motivating students to learn science, achieving conceptual learning and understanding of science concepts, and examining the perceptions and experiences of participants in this study, a constructivist framework (social-cognitive and sociocultural) seems consistent with the focus of this study.

2.1.5. Learning and motivation

In classroom contexts, student motivation is the measure of the level of energy invested and willingness to participate in learning activities (Brophy, 2010b). The comments by Schunk, Pintrich, and Meece (2008) that “motivation is an important quality that pervades all aspects of teaching and learning” (p. vi) and Townsend (2011) that “motivation is at the heart of school learning” (p. 131) suggest that motivation can play an important role in learning. Learning and motivation may go hand in hand for the completion of a learning task as motivation can affect new learning or development of a previously learned skill, behaviour or strategy (Schunk et al., 2008). Schunk et al. (2008) argue that the role of motivation during learning is critically important in that motivated learners show interest and readiness to engage in learning activities, believe in their capabilities, apply cognitive and self-regulatory strategies, expend effort, persist longer even in the case of adversities and overall, achieve well in education. Hardré (2015) states that motivation is essential for effective learning from both the behavioural-affective and the cognitive-developmental perspectives. From the behavioural-affective aspect, motivation promotes engagement, attention, effort and determination to learn and master skills, whereas, from the cognitive-developmental perspective, motivation helps the learner to process information, integrate new knowledge with the prior beliefs, enhances log-term memory and ensures retrieval, set and achieve *smart* goals, promote mastery goal orientation, and ensures deep learning (Hardré, 2015). Therefore, Hardré (2015) maintains that motivation supports learning by helping the learner to integrate new knowledge and skills with the previously learned, to develop rich and adaptive skills, and to promote active learning and problem solving.

In terms of the relationship between learning and motivation Schunk et al. (2008), however, comment that motivation shows a reciprocal relationship with learning and performance. The relationship is seen as reciprocal in that motivation affects learning and achievement and what students learn and achieve in return affects their motivational state. The reciprocal but strong relationship between motivation and learning as suggested by Schunk et al. (2008) and others such as Brophy (2010a, 2010b), therefore indicates that motivation is an essential condition for effective learning to occur. However, Schunk et al. (2008) comment that motivation is not necessary for learning, although it accelerates learning. According to St. George, Riley, and Hartnett (2014) learning and motivation are intimately intertwined constructs. Some people equate motivation with learning, achievement, performance and engagement but these psychological constructs are different, although they seem similar (Middleton & Perks, 2014). Nuthall (2007), however, argues that although motivation plays an important role, it is not a sufficient condition for effective learning. Nuthall (2007) contends that:

> Much of what goes on in classrooms is based on the belief that if students are interested and involved in an activity, they will learn from it. Being attentive and engaged is equated with learning. However, students can be highly motivated and actively engaged in interesting classroom activities, yet not be learning anything new. Learning requires motivation, but motivation does not necessarily lead to learning. (p. 35).

Nuthall (2007) therefore maintains that motivation is essential for learning, but just because motivation is present, it does not necessarily mean that learning is occurring. In other words, students may seem highly engaged in and motivated to do a learning task, but this does not mean that they will accomplish the required learning goals. Many researchers, such as Anderman and Dawson (2011), Boekaerts (2010), Brophy (2010a), Townsend (2011), Wentzel (2005a), Wigfield, Cambria, and Eccles (2012) also confirm the important role that motivation can play in academic learning based on their extensive research on motivation in classroom learning contexts and school settings. These researchers have used different terms, such as motivated learning, learning with motivation, academic motivation, motivation towards learning and motivation to learn, to refer to the study of motivation in learning situations. In this study the term ‘motivation to learn’ as used and suggested as a psychological construct by Brophy (2010b) is used throughout the thesis to refer to motivation towards science learning of students. This is explained and discussed in section 2.3.

2.2. Motivation frameworks

Motivation is a more frequently sought, however less often found, characteristic of schools, classrooms and students (Middleton & Perks, 2014). For Townsend (2011), motivation “is at the heart of school learning” (p. 133). Schunk et al. (2008) also view motivation as an important quality that permeates all aspects of education. As discussed in the previous sections the nature of learning is very complex, and motivation is no exception. Motivation is a highly complex psychological construct (Dörnyei & Ushioda, 2011) because numerous and different types of factors can account for and affect its origin and sustenance. Dörnyei and Ushioda (2011) are of the view that any existing single theory is insufficient to explain and predict motivation because motivation deals with the complex and doubtful notion of human behaviour. They further comment that since no single theory can capture the comprehensive nature of all possible human motives, “devising an integrative ‘super-theory’ of motivation will always remain an unrealistic desire” (p. 4).

One of the reasons for this complexity might be because motivation is not directly observed but it is inferred from the actions and behaviours shown by people (Schunk et al., 2008; St. George et al., 2014). Another reason, as contemporary learning theories and their comprehensive picture presents, is the effect of personal, social, emotional and contextual factors and the interplay between them. For example, a behaviour exposed by an individual may be the result of that individual’s needs, drive, will and volition. These needs and efforts are further affected by internal factors such as interest, fun, enjoyment and curiosity, as well as external rewards such as value and the importance given to an activity. Further, any depicted behaviour has short-term (current, personal importance) goals and long-term (future) goals involved with it. Additionally, expectancy of success in an activity is dependent on the competency, attribution and task-value beliefs, control and regulation of many self-related features, task difficulty and environmental conditions. On top of everything, social, emotional, contextual (cultural) elements mingle with these personal-internal-external factors to make the concept of motivation very complex, interesting and therefore research-worthy (Dörnyei & Ushioda, 2011) for educators.

Another major complexity associated with motivation is the cause-process-effect and the temporal nature of theoretical constructs. Some theories, for example Wigfield and Eccles's (2000) *Expectancy-Value* theory, consider motivation in terms of, and generally focus on, causal constructs. Others, such as the *Attribution Theory* by Weiner (1992) and the *Learned Helplessness* theory of Peterson, Maier, and Seligman (1995), focus on the affect aspects of the motivational constructs. In contrast, some other theories focus on the process aspects, such as interest, enjoyment, flow and different emotional orientations during the process of an activity. The temporal aspect of motivation suggests that motivation develops gradually and does not remain constant over the course of time, particularly when the task usually takes a long time to accomplish (Dörnyei & Ushioda, 2011). For example, during the course of doing a PhD, individuals experience varying degrees of motivation that can generally differ across days, weeks, months, years and even chapters. However, despite the complexities involved in understanding motivation fully, there is a wealth of important and comprehensive information that can assist understanding many of the processes involved in pursuing different activities and tasks in academic and social life (Middleton & Perks, 2014).

2.2.1.1. Motivation defined

Because of the above-mentioned complexities, it seems difficult to define motivation clearly. Townsend (2011) comments on this inability to define motivation stating motivation is "a word in crisis" because of the "overwhelmingly complex array of loosely connected theories and concepts" (p. 130) that try to define and explain it.

However, many researchers, have tried to define it based on their foci, findings and experiences. Schunk et al. (2008) defines motivation as a "process whereby goal-directed activity is instigated and sustained" (p. 4). This definition suggests that motivation is a process and not a product, the motive has a goal based on which the activity is chosen, initiated and continued even in the case of difficulties. According to Brophy (2010b), "motivation is a theoretical construct used to explain the initiation, direction, intensity, persistence, and quality of behaviour, especially goal-directed behaviour" (p. 3). From this more comprehensive view, motivation is a state of behaviour which explains why people do what they do. It is a state in which people take the initiative to do something, direct their full energy and persist longer even if problems arise, to achieve whatever they want to. Townsend (2011) defines motivation as "a biological or psychological process, a hedonistic desire to seek pleasure and avoid pain, an unconscious or subconscious process, or a conscious, goal-oriented, strategic process" (p. 119). Townsend's definition points to the self-indulgent (internal) nature of the process of motivation in which a task is chosen to seek enjoyment and to avoid discomfort in any of the conscious, sub-conscious or unconscious states of mind. Townsend also cautions educators about the overly simplistic and mechanical nature and meaning of the concept of motivation and suggests teachers to see motivation as "an *internal psychological* state that accounts for the initiation, direction and maintenance of behaviour" (p. 120; emphasis in original), instead of "'giving' motivation to students" (p. 130) which presents its mechanical nature. However, all of the definitions presented above have some common points of agreement: the choice of a particular task, the perseverance to accomplish it and the energy expended to achieve it. In other words, motivation explains why people do what they do, how long they sustain it and how far they go to accomplish it.

2.2.1.2. Evolving views of motivation

Motivation as a concept has evolved over time, starting from the process of satisfying individual's needs and desires to recent sociocultural and person-in-context views. Historically, motivation has been conceptualised and understood as an individual's initiative to fulfil their basic needs (Maslow, 1970, 2013). Maslow (2013) describes the process of satisfying a variety of individual needs in terms of a hierarchy, spanning from the lower level basic needs, such as physiological, safety, belongingness; to the higher level needs, such as self-esteem and self-actualisation. Maslow (1970) also points to the gratification of cognitive impulses such as curiosity and the desire to know, understand and learn new things and state them as equally important, naming them *conative* needs. According to Maslow (1970), any human behaviour should be understood as the integration of many impulses, desires and motivations and not in terms of fulfilment of any single need. This suggests that there could be multiple determinants of a single behaviour.

Maslow’s theory of human needs was the first attempt to develop a comprehensive model to explain behaviour. Keeping in view the diversity of many determinants, and recognising the *identity crisis* (Townsend, 2011) with the meaning and nature of motivation construct, Ford (1992) developed another comprehensive theory of motivation: the *Motivational Systems Theory* (MST). Ford synthesised 32 theories of motivation and proposed a coherent model/framework of different psychological constructs which can be used to describe motivated or unmotivated behaviour. From this integrated MST framework, Ford derived 17 principles which can be applied to motivate people in different settings, especially enhancing motivation for learning and achievement in schools. In MST, Ford puts an excessive emphasis on the role of emotions along with goals and personal agency beliefs (Schunk et al., 2008) and describes motivation in terms of interactions between these three constructs. Ford explicitly stated that the MST is a comprehensive theory of all human behaviour, not only for school achievement, and is “generally compatible with existing theories of motivation and does not try to replace them” (p. 11). Leonard, Beauvais, and Scholl (1999) presented another comprehensive motivation framework of motivation in organisational settings. These authors proposed five factors as sources of motivation which affect human behaviour: instrumental motivation such as rewards and punishment; intrinsic motivation such as enjoyment, interest and fun; goal internalisation; internal self-concept-based motivation; and external self-concept-based motivation. Out of these five factors, the first and the last factors (instrumental and external self-concept-based motivation) produce an externally-oriented behaviour, whereas the rest of the three determine more intrinsically-oriented behaviours. These five factors altogether influence a person’s overall behaviour, although, they vary in their strength or degrees.

Conversely, most of the motivational theories to date have focussed on and highlighted a few selected constructs (for example drives, needs, traits, goals and self-beliefs) and thus lack comprehensiveness (Dörnyei & Ushioda, 2011; Townsend, 2011). Schunk et al. (2008) present the evolution of earlier motivation theories in terms of the *volition/will* views of Wilhelm Wundt and William James, *instinct* based views of William McDougall, the *psychic energy* view of Freud and the *classical* and *operant conditioning* of Ian Pavlov and B.F. Skinner. These earlier, typically behavioural, theories were criticised for their inability to explain and predict all human behaviours (Schunk et al., 2008). Subsequent *Humanistic theories* of motivation, such as Carl Roger's *client centred therapy* and Abraham Maslow's *need hierarchy theory* recognised the important roles of cognition and emotion and suggested a need to study the holistic nature of human motivation. More recent views of motivation see it in terms of an individual's thoughts, goals, beliefs, feelings, and self-representations, and stress the cognitive, social and cultural (contextual) situation of motivation (Schunk et al., 2008). These can be categorised in terms of cognitive, personal-agency beliefs, socio-cognitive, socio-cultural and context specific theories, some of which are discussed in the following sections.

2.2.1.3. Cognitive theories of motivation

Cognitive theories of motivation and motivational constructs became prevalent during the second half of the 20th century as a response to the behaviourist theories (Dörnyei & Ushioda, 2011). Cognitive theories put emphasis on the central role of cognitive structures and mental processes such as information processing, thoughts, self-related beliefs and goals as determinants of motivated behaviour and action (Schunk et al., 2008). From a cognitive point of view of motivation, a person's desire to learn, to achieve, to satisfy curiosity, to resolve cognitive dissonance and establish a balance between ideas, thoughts, values and beliefs over time serve as important motives to take action and sustain those actions. Key cognitive theories which inform teaching and learning, and find numerous applications in education are: Goal theories (goal setting, goal orientation, and goal content and multiplicity); expectancy-value theories (achievement motivation, attribution, self-efficacy, self-worth, and task value theories); social-cognitive, self-determination and sociocultural theories. Brief discussion about these follows.

Goal theories

Goal theorists assumes that individuals perceive, choose, instigate and persist in an activity to achieve something (Schunk et al., 2008). Goals can provide the direction in which individuals want to act and can guide them to approach and avoid something in relation to achieving their goals. According to Townsend (2011), "goals are the cognitive representations of the force or energy that initiates arousal in motivation" (p. 121) and thus plays an important role in motivation. These goals can either be short-term (proximal; of immediate importance) or long-term (distal; such as career or life). Different types of goals can be classified on the basis of the temporal or process nature of motivation. For instance, Ford's (1992) taxonomy suggested 24 types of human goals; 11 of the *desired within-person consequences* divided into three broad categories (affective, cognitive and subjective organisation goals) and 13 types of *desired person-environment consequences* goals, similarly divided into three broad categories: self-assertive social relationship goals, integrative social relationship goals and task goals. Ford asserted that a single behaviour may be guided by a number of goals at a given time and also commented that behaviour steered by many goals usually results in powerful motivation. Goal theories typically cover three types of varieties: goal setting, goal orientation, and goal content and multiplicity.

The goal setting theory of Locke (1996) places emphasis on the process of setting goals for enhancing motivation. According to Locke (1996), difficulty, specificity and commitment towards achieving a goal play an important role in determining individuals' motivation. A higher level of motivation may be ascribed to a person who sets an achievable but challenging goal and believes that achieving the goal is likely (expectancy) and is personally important (value). In this respect, Locke's goal setting theory is compatible with the Wigfield's (1994) expectancy-value theory. Motivation levels also depend upon the nature of short-term and long-term goals. Dörnyei and Ushioda (2011) make the distinction between proximal and distal goals clear and caution that goals should not be considered as "outcomes to shoot for" (p. 21) but they also can serve as standards by which performance can be monitored and evaluated. For instance, in the case of long lasting tasks such as completing a PhD, there is the main goal of writing a better thesis and passing the examination. However, setting of proximal goals such as mastering academic writing skills, knowledge of the research process (methods, methodology and tools), knowledge of important theoretical frameworks, writing an interesting research proposal, managing study and life, managing supervisors, satisfying examiners' expectations etcetera, may also impact motivation during the programme. These sub-goals may provide information and feedback about performance, and achieving these sub-goals generally may help to achieve the distal goal of completing a doctorate. Although most of the goal setting theories were developed in work and organisational settings, they are equally applicable in the educational context (Schunk et al., 2008). In relation to motivating students to learn something, Schunk et al. (2008) suggest that proximal goal setting, which is setting short-term, achievable but challenging goals, may boost motivation by improving self-efficacy, intrinsic motivation and self-regulation of learning.

The goal orientation theory, proposed by Carol Dweck (1986), Carole Ames (1992) and a few other researchers such as Duda and Nicholls (1992) identified two major goal orientations: performance goals and mastery (learning) goals. Much of the research in education related to goals is devoted to the difference between these goal orientations (Schunk et al., 2008). According to Elliot (2005), the main purpose of behaviour embracing a performance orientation is to establish superiority over others, demonstrating competence, to achieve high scores/grades and avoid displaying incompetence, whereas students who adopt a mastery approach focus on personal improvement, understanding, and developing skills, competence and task mastery. Mastery-oriented students believe that the efforts they put into any task will lead to success and therefore, they focus on self-improvement and growth (Dörnyei & Ushioda, 2011). In contrast, performance-oriented students view learning as a way to achieve the goal and social appreciation (ibid.). An extensive body of research has confirmed that mastery-oriented students show higher motivation and better learning in comparison to performance-oriented students (Schunk et al., 2008). For example, Townsend (2011) notes that the mastery-oriented students, generally demonstrate better self-efficacy, maintain interest and effort, show greater appreciation of value, persist longer in case of difficulties, adopt effective learning strategies, set achievable and challenging goals and monitor their progress towards achieving their goals. To ensure students' enhanced motivation and learning, Linnenbrink (2005) argues that it is essential to consider interaction between students' personal goal orientations and the goal orientations which a pedagogical environment of the classroom focus at. Therefore, it is important to coordinate these personal and multiple goals of classrooms as they may overlap at one time or exist in conflict at another (Townsend, 2011; Wentzel, 2005a).

Contrary to goal-setting and goal-orientation theories of motivation, which essentially focus on individual motivation and performance, goal content and goal multiplicity theories focus on the actual goal content of an individual's social and multiple goals (Wentzel, 2000). Goal content theory, proposed by Wentzel (2000), which was initially drafted by Wentzel and Wigfield (1998) is an extension of Ford's work on goal content (Dörnyei & Ushioda, 2011). According to Wentzel (2000) the goal content refers to the specific cognitive representations of what people try to achieve. Research by Wentzel (2000; 2005) and Wentzel and Wigfield (1998) suggests that in a single classroom activity, students may actively pursue multiple goals at a given time. For example, a group activity may serve personally important, cognitive, social, emotional and collective goal satisfaction through enhancing their knowledge, understanding, and skills; satisfying curiosity; establishing relationships; feeling included, accepted, and excited; and displaying responsibility. Similarly, research by Urdan and Maehr (1995) examines the specific impact of social academic goals and social motives on academic achievement motivation and suggests goal theorists should include social goals. From this point of view, it seems that social goals such as social responsibility, social relationships and social interaction can affect individual motivation in a group or classroom situation. Moreover, as Wentzel (2000) argues, goals are "socially derived constructs that cannot be studied in isolation of the rules and conventions of culture and context" (p. 106), the emphasis on social context of goal development is growing. This growing emphasis on socio-cultural aspects of motivation has encouraged researchers such as Elliot (2005) Horst, Finney, and Barron (2007), Walker (2010) and colleagues (R. Walker, Pressick-Kilborn, Arnold, & Sainsbury, 2004; R. Walker, Pressick-Kilborn, Sainsbury, & MacCallum, 2010) and Wentzel and her colleagues (Wentzel, 2004, 2005a, 2005b, 2009; Wentzel, Baker, & Russell, 2014; Wentzel & Brophy, 2014) to examine and better understand various dimensions of social and contextual effects on motivation and achievement. These sociocultural views are discussed in subsection 2.2.1.5.

Expectancy-value theory

Expectancy-value theory is perhaps the most influential and long-standing cognitive motivation theory (Dörnyei & Ushioda, 2011), which can be expressed by a simple equation: *expectancy x value = motivation* (Wigfield & Eccles, 2000). This equation suggests that an individual's motivation to accomplish a task (or willingness to expend effort on a task) is a multiplicative function of the expectancy of success and the value that the individual ascribes to the task. The greater the perceived probability of the task completion and the greater the value that a person assigns to the activity, the higher the motivation to achieve. On the other hand, the motivation to achieve diminishes if either of the parts is perceived to be at a low level. Further, the motivation to achieve is severely affected if either of the factors is missing and it is unlikely that an individual will choose such an activity and invest effort in it (Schunk et al., 2008; Wigfield, 1994). For example, if a person is convinced that he/she cannot succeed in an activity no matter how hard he/she tries and if the carrying out of that activity does not result to a valued outcome, the person will not plan to carry out that activity. The expectancy of success is future oriented (Schunk et al., 2008) in the sense that it refers to the belief a person has in relation to an upcoming or future task. The expectancy further depends upon many factors, such as self-perceptions of ability or competence (self-efficacy), self-related beliefs (self-worth and self-concept) and perceived causes of outcomes (attributions). Many researchers such as Albert Bandura, Martin Covington, Elliot and Dweck, and Bernard Weiner have extensively discussed the important roles played by these constructs in determining an individual's motivation and proposed their respective theories. These constructs, except self-efficacy, while important are beyond the scope of this discussion.

According to self-efficacy theory (Bandura, 1997), an individual's judgement of their skills, capabilities and competence largely determines the choice of an activity, level of aspiration, amount of effort employed and level of persistence to successfully accomplish that activity. Persons with strong levels of self-efficacy generally show high achievement motivation, approach an activity with confidence, show a task-focus approach and increase and sustain effort in the case of adversities (Dörnyei & Ushioda, 2011). In contrast, individuals with a low sense of self-efficacy perceive difficult tasks as personal threats, adopt a task-avoidance approach, and put attention on their personal deficiencies rather than planning for task accomplishment (ibid.). Given that the self-efficacy construct involves cognitive processing of different types (perceptions, beliefs, opinions, feedback, persuasion, past experiences, task-strategies, observing peers and models), it is theoretically related to social-cognitive theory (Schunk et al., 2008). More details about self-efficacy are presented in the following subsection 2.2.1.4.

The value aspect of the expectancy-value equation refers to both the value of rewards that success brings, as well as the value that engagement in the task brings (Dörnyei & Ushioda, 2011). This perceived task value generally is a strong predictor of whether an individual would want to pursue and engage with the task (Townsend, 2011). Eccles (2005) and her colleagues (e.g. Eccles & Wigfield, 2002; Wigfield & Eccles, 2000; Wigfield, Eccles, Roeser, & Schiefele, 2008) have developed a comprehensive model of task values and proposed four components of task value: intrinsic value, attainment value, extrinsic utility value and cost beliefs. The intrinsic value refers to the interest, enjoyment and fun experienced in doing an activity. The attainment value signifies the importance of doing well on an activity. The utility value is the belief about the importance of the activity for future goals and the cost belief denotes the perceived negative outcomes of doing an activity, such as anxiety, fear of failure, loss of time and other sacrifices due to preferring an activity over others. These four types of value beliefs influence motivation and generally function together to calculate the total perceived value of the task at hand (Schunk et al., 2008; Wigfield, Tonks, & Klauda, 2009). Therefore, in relation to a learning activity, it is likely that students will be motivated to engage in and to do the activity if they enjoy doing the activity, believe that it is useful for their immediate and future goals, want to do it well and perceive little or no cost in doing the activity (Townsend, 2011). This task value aspect is a very important aspect of *motivation to learn* and is further discussed in section 2.3.

2.2.1.4. Social cognitive theory of motivation

Social cognitive views of motivation proposed by Bandura (1991), and Dweck and Leggett (1988) assume that the interaction and relationships in social settings can influence an individual’s motivational state. According to Pajares (2002), Bandura’s self-efficacy theory was derived from his social cognitive views of learning (Bandura, 1991) and from the comprehensive social learning theory (Bandura, 1986). Self-efficacy theory places emphasis on the role of cognition and context, which was lacking in behavioural and earlier cognitive views of learning. Social cognitive theory describes the reciprocal interactions among personal (cognitive, affective and biological), behavioural, and social/environmental factors (Schunk & Usher, 2012). From this reciprocal theoretical perspective, human functioning (performance) is seen as a product of dynamic interplay of these three factors. Individuals learn knowledge, skills, beliefs, rules, attitudes, emotions and strategies by interacting with others, therefore most of human behaviour and learning happens in social environments (Schunk & Usher, 2012).

Personal ability and competence beliefs play a key role in determining motivation and are affected by social interactions. According to Bandura (1997), an individual generally employ four sources of information to judge their self-efficacy beliefs: performance outcomes (previous performance and mastery experiences), vicarious experiences, verbal persuasion and physiological feedback. Bandura (1997) outlines the important role that mastery experiences can play in determining performance (Usher & Pajares, 2006). For example, if an individual is trying to accomplish a similar task to one they have accomplished before, they are more likely to experience high levels of self-efficacy as a result of previous mastery experiences (Usher & Pajares, 2006). Individuals may also develop a strong sense of self-efficacy through observing others (models and mentors) through second-hand experiences. A model's success or failure can impact the self-efficacy beliefs to a large extent (Usher & Pajares, 2006). The social persuasions (words of encouragement and praise) which individuals receive from significant others also play an important role in the development of self-efficacy beliefs. In classroom contexts, teachers' appraisal, informative feedback, and judgments about students' academic performance can impact self-efficacy beliefs. Physiological and emotional arousal states such as enjoyment, boredom, stress, anxiety, fatigue and feeling of achievement can also determine the perceived levels of self-efficacy. Individuals can enhance physical and emotional well-being and thus can strengthen self-efficacy by increasing positive emotional arousals and reducing the negative feelings (Pekrun, 2006, 2013).

Bandura (1997) also highlights the four important cognitive processes which can affect an individual's motivation: self-observation, self-evaluation, self-reaction and self-efficacy. These four factors are inter-related and each may impact individual motivation and performance (Schunk & Usher, 2012). In relation to the main role played by self-efficacy in motivation, Bandura (1997) states that "people's level of motivation, affective states, and actions are based more on what they believe than on what is objectively true" (p. 2). This statement suggests that an individual's self-related beliefs (for example about competence and skills) largely determine the level of motivation and performance and thus may differ from the reality of the competence required to accomplish a task. In addition to self-efficacy beliefs, Bandura's social cognitive theory also emphasizes the important role that self-regulatory processes (self-observation, self-reaction and self-evaluation) can play in motivation (Schunk & Usher, 2012). Self-regulation is the process of initiating and sustaining thoughts, behaviours and emotions and their organized alignment towards achieving the desired goals (B. J. Zimmerman, 2001, 2002). In his later writings, Bandura labels these self-regulatory processes as an 'agentic perspectives' of motivation (Bandura, 2001, 2006). From an agentic perspective, an individual plays an active role in self-organising, self-regulating, and self-reflecting towards development, adaptation, and change in his/her life. From this agentic viewpoint individuals deliberately influences their functioning and performance, acting as controllers and contributors rather than merely as the product of their life situations (Bandura, 2006). These self-regulatory processes have been reported to promote learning and sustain motivation towards academic achievement (learning) by Brophy (2010b), Schunk (2001), Schunk et al. (2008), B. J. Zimmerman (1989) and B. J. Zimmerman (2002). In relation to the social context and group motivation, Schunk and Usher (2012) also describe the role of *collective efficacy* beliefs and *collective agency* in influencing individual motivation. According to Schunk and Usher (2012), collective efficacy perceptions refer to an individual's perceptions of the capabilities of the group as a whole, whereas collective agency means individuals' shared perceived abilities of accomplishing an activity as a group. These perceptions of different constructs have important implications for the cultural and situated nature of group learning in classrooms (Schunk & Usher, 2012; Wentzel, 2005b).

2.2.1.5. Sociocultural theories of motivation

Since the start of 21st century, researchers in the areas of motivation and learning have increasingly focussed their attention on social contexts and situational aspects (Nolen & Ward, 2008). This focus can be ascribed to researchers' increased interest in the social, cultural and contextual nature of cognition, emotion and beliefs (Schunk et al., 2008). In the learning and motivation literature, different researchers have described the social impacts of learning and motivation using different names, such as sociocultural, situative, 'person-in-context' (Volet, 2001) and 'social influence' (R. Walker et al., 2004) theories. Earlier and seminal sociocultural views of motivation (for example

Sivan, 1986) described it as a conceptualisation of 'socially constructed motivation'. These views see motivation as a socially negotiated process rather than instigated by an individual. R. Walker et al. (2004) label these proponents as 'social influence' theorists in order to differentiate from those who consider motivation as more or less internal and individual phenomena (e.g. Perry, Turner, & Meyer, 2006; Townsend, 2011). Sociocultural views of motivation stress the social nature and social origin of motivation (R. Walker, 2010) in order to explain how interest, goals and values are constructed in social situations, develop through interactions and are exhibited in collective activities (R. Walker et al., 2010). Students' motivation and academic achievement are greatly affected by the sociocultural influences of friends, families, communities, peers and culture (Schunk et al., 2008). The social origin and social construction of motivation can be considered as a result of Vygotskian (1978) concepts such as the *zone of proximal development* (*ZPD*), peer learning, assisted learning, interpersonal relations and transformative internalisation. Walker (2010) describes the process of social influences commenting that through these processes (for example ZPD) motivation is "conceptualized as social in nature, [and] is internalized to become an individual process" (p. 713; emphasis added). Wentzel and Brophy (2014) also refer to the equivalent *motivational ZPD* and describe it in terms of the *optimum match principle*. According to the optimum match principle, there should be a match between the previous knowledge and experiences of an individual and the features of the learning activity, so that it can stimulate the interest of the individual (R. Walker, 2010; Wentzel & Brophy, 2014). As a result of the stimulated interest, the individual values the activity and wants to pursue it. In classroom contexts, teachers and peers can help students to see and appreciate the value of learning by making the learning activity interesting, relevant and meaningful, and ensuring the motivational optimum match principle is met. Walker (2010) notes that the scaffolding provided by peers and teachers to match the learning activity to an individual's interests and abilities, and processes such as cognitive structuring, makes the motivational ZPD inherently motivating. In relation to classroom contexts, R. Walker (2010) further describes the ZPD as a *socially mediated space* which is shaped by different types of relationships and interactions and thus can take the relational or emotional/affective form to develop students' positive relations and emotions. The creation of this motivational ZPD has numerous implications for the development of ability, skills, emotions, relations and interest among peers and group members in a classroom.

From a sociocultural point of view, in addition to peers and teachers, parents and community members (such as role models and distinguished people) can also affect an individual's motivation to achieve something. Parents' self-efficacy has been reported as "positively related" to and bears an "additive" and direct influence on students' self-efficacy, self-concept, task value and academic achievement (Townsend, 2011, p. 127; Townsend & Choi, 2004, September). Townsend and Choi (2004, September) carried out empirical research in New Zealand schools and concluded that children's reading motivation can be enhanced as a result of interaction between the school and home learning environment.

2.2.1.6. Recent views of motivation

More recent views of motivation emphasise the integration of individual, social, contextual and situative aspects to propose a comprehensive, systemic (Hardré, 2015) and dynamic (Dörnyei & Ushioda, 2011; Järvelä & Volet, 2004) study of motivation. Hardré (2015) argues that much of the educational research has focussed on discrete, narrowly defined and single motivational constructs such as goals, traits, values, self-efficacy and self-determination, and therefore has neglected the holistic nature of complex constructs such as learning and motivation. Hardré (2015) stresses the need to consider the systemic approach to studying motivation, stating that modern learning environments are extremely, diverse, complex, and dynamic (intellectually, socially and emotionally interactive spaces). A systemic approach to motivation considers the integration of the many separately functioning elements such as personal, inter-personal, behavioural, physical, social, economic, environmental, cultural, contextual, regional and national, in order to understand the holistic phenomena (Hardré, 2015). In these complex environments learning can happen in and out of the formal spaces, such as museums, virtual spaces, workshops, art studios, garages, homes, training centres or boardrooms. Therefore, Hardré (2015) suggests that it is important to recognise that modern learning environments are "not discrete, but overlapping, integrated and dynamically connected" (p. 21). Other researchers (for instance, Järvelä & Volet, 2004; Volet & Järvelä, 2001) also stress the need to examine the dynamic and comprehensive motivational constructs as a result of the diversified, ever changing, expanding and complex nature of learning and learning environments. Social learning environments are referred to as dynamic and interactive by Järvelä and Volet (2004), because these provides opportunities for social interactions and relationships in the process of collaborative knowledge construction. Further discussion on motivation in collaborative learning environments is provided in section 2.3.

2.3. Motivation to learn

In classroom contexts, Wentzel and Brophy (2014) define *motivation to learn* as "a student's propensity to value learning activities: to find them meaningful and worthwhile, and try to get the intended benefits from them" (p. 217). In relation to this definition, learners first perceive the learning activity valuable in terms of their short-term or long-term goals and then show initiation and choice, take action and expend effort with the intention to acquire the perceived benefits from the intended learning activity. Wentzel and Brophy (2014) further argue that motivation to learn is not directly related to either intrinsic or extrinsic motivation; rather, it is concerned with the adoption of learning goals and related learning strategies in a learning situation. According to Brophy (2010b), teachers can motivate students by stimulating them to realise the value of content and guiding them to design and apply learning strategies to understand it. Brophy (2010b) also advises teachers to help students make motivation to learn their goal and to focus on the learning goals rather than intrinsic or extrinsic motivation. According to Woolfolk (2014) motivation to learn involves more than wanting or intending to learn: it involves beliefs, perceptions, developing and adopting learning strategies, intentions to understand content and master important skills, taking control of own learning and emotions, setting goals and planning for achieving those goals. Motivation to learn is, therefore, more cognitive in nature than its related concepts of interest and intrinsic motivation, which are more affective in nature (Brophy, 2010b). Intrinsic motivation and interest are considered more affectively oriented due to the fun, enjoyment and pleasure aspects involved. However, in relation to a learning activity, motivation to learn includes affective as well as cognitive elements, both of which affect the achievement of learning outcomes (Brophy, 1987).

Jere Brophy (Brophy, 1983, 1987, 1988) developed the concept of *motivation to learn* in academic contexts by integrating the constructs involved in motivation and learning processes. This concept was further developed by Brophy (2010b), and Wentzel and Brophy (2014) after their extensive research and was suggested as an academic psychological construct. The concept is similar to motivation to achieve (Alderman, 2008), achievement motivation (Wigfield & Eccles, 2000; Wigfield et al., 2008) or motivation to succeed as seen in general motivation literature but has a more academic and cognitive orientation. Subsequently, researchers such as Boekaerts (2002, 2010) and, Middleton and Perks (2014) researched the concept in detail and suggested some important principles for motivated learning in classroom contexts.

Boekaerts (2002) suggests that in order to encourage students to become self-regulators and independent learners, teachers need to know about the principles that inform motivated learning. Boekaerts (2002) describes eight principles that have emerged from empirical research which can be adapted and applied to different classroom contexts and learning environments. The eight principles broadly emphasise students' motivational beliefs, values, opinions, perceptions and conceptions about self, teachers, content and classroom environment, and teachers' knowledge of these beliefs and their association with or impact on classroom learning environments. Boekaerts (2002) states that teachers' knowledge, analysis and acknowledgement of these motivational beliefs can help them in designing motivational strategies and creating motivating learning environments in schools which are best suited to students' beliefs, competencies, interest and future goals. This understanding of students' beliefs about content and teaching-learning strategies can also help teachers to understand what and why students consider something important and valuable. Teachers also need to help students develop a mastery goal-orientation, and develop willpower and persistence. In addition, students should be trained to attribute success and failure to effort, learn from mistakes, and balance their own, peers', teachers' families' and social goals so that they can develop autonomy and self-determination (Boekaerts, 2002).

In a later publication, through the polished and more comprehensive eight *key principles*, Boekaerts (2010) stresses the crucial role that positive (favourable) and negative (unfavourable) emotions about the learning environment can play in students' learning, in addition to motivational constructs. Boekaerts (2010) proclaims that the duo of motivational and emotional constructs can ensure that students develop the required/intended knowledge, competence and skills in a meaningful way. Therefore, Boekaerts (2010) urges teachers to integrate them in their teaching so that students feel more competent and find the classroom learning meaningful, more interesting, enjoyable and purposeful.

Other researchers such as Brophy (2010b), Middleton and Perks (2014), and Wentzel (2005a, 2009) emphasise the important role played by teachers' beliefs, classroom practices and strategies, the promotion of students' voice, and positive relationships with peers and teachers in motivating students to learn meaningfully. In relation to the relationship between motivation and teaching, Boekaerts (2002) argues that good teaching advances motivation whereas bad teaching destroys motivation. Teachers can generate intrinsic motivation and make classroom learning activities meaningful by making the intrinsic value explicit, outlining applications in other areas/subjects/life and relating the content to students' skills, interests and goals (Boekaerts, 2002). This can be achieved by including students in goal-setting and discussions about the importance, relevance and applications of subject matter in life. However, it is only rarely seen in a classroom that a teacher invites students' opinions about what makes a learning activity interesting, fun, important, relevant, easy, boring, challenging or difficult (Shumow & Schmidt, 2014).

Motivation to learn generally develops gradually through a complex mental process which involves intention formation, goal setting, planning, organising, taking action, monitoring progress and analysing the outcomes (Middleton & Perks, 2014). Different motives may affect motivation to learn during these processes and phases. In relation to learning achievement, some motivation constructs such as competency and efficacy beliefs, learning achievement value, learning goal orientations and learning interest value may account for better or worse learning outcomes. Students' unfavourable beliefs about their skills, competence, ability and self-concept may impede their learning as they direct students' attention away from the task rather than encouraging them to try and adopt motivational learning strategies (Boekaerts, 2002, 2010). According to Middleton and Perks (2014), students' beliefs about the content (generally known as prior knowledge or conceptions) are equally important to examine as these can be the cause of misconceptions held by students. Moreover, students are reported to be very smart and successful in hiding their beliefs and conceptions about the subject matter (Boekaerts, 2002). In addition to students' competence and prior knowledge beliefs, Boekaerts (2002) emphasizes that students' motivational beliefs also include beliefs about the efficiency and effectiveness of teaching and learning strategies. Similarly, Meece, Herman, and McCombs (2003) highlight the need to examine students' perceptions of teaching and learning environments.

In relation to the contextual and situational impacts of motivation in classroom learning, there are two areas of particular interest: the instructional context (instructional task and strategy) and the social, psychological and cultural influences from peers, teachers, family, community, culture, school and society (Dörnyei & Ushioda, 2011). Anderman and Dawson (2011) comment that teachers' choice and design of the instructional activities can influence students motivation to learn. The impact of a learning activity and task on students' motivation to learn (interest, engagement) has important implications for the field of instructional design. Teachers can encourage students to learn from and with other students and can design co-operative learning environments by discouraging competition, avoiding social comparison, not describing assessment and evaluation criteria, providing individual, rather than public, feedback and discussing the group strengths rather than individual abilities (Middleton & Perks, 2014). Effective collaborative learning usually boost motivation to learn and self-efficacy among all members of the group (Dörnyei & Ushioda, 2011). Boekaerts (2002), Brophy (2010b) and Schunk et al. (2008) also reveal similar findings and suggest that by creating collaborative and mastery oriented learning environments, teachers can motivate students to learn and make learning meaningful. Boekaerts (2001) recommends that instruction procedures and processes should be aligned to the psychological needs and goals of students, which however change continuously as a result of their developing knowledge, interests, values, skills and changing self-beliefs (Boekaerts, 2002). The classroom learning environment (instructional, social as well as psychological), according to Meece, Anderman, and Anderman (2006), is directly associated with students' motivation and achievement. These aspects suggest that the curricular activities, quality of instruction, quality of teacher behaviour, interactions among peers, teacher-student interactions and different types of relationships are crucial elements to consider while designing classrooms as contexts for motivated learning (Perry et al., 2006). In addition to peers, teachers and classrooms, schools as a whole can also impact students' motivation through the values they promote (Dörnyei & Ushioda, 2011). For example, a school in New Zealand has the motto (vision): *Working Together, Thinking Together, and Learning Together*, and this school aspires to produce confident, connected and active learners. These values are put into action by the school staff in collaboration with parents and community members involved. Meece et al. (2006) also suggest that when the school environment focuses on improving knowledge, skills, understanding and mastering learning, students are likely to adopt a positive and adaptive approach to learning; in other words a motivated learning approach.

The contextual nature of motivation in collaborative learning environments has been widely discussed and debated over the last few years (for instance, Järvelä, Järvenoja, & Veermans, 2008; Järvelä, Volet, & Jarvenoja, 2010; Li, Hung, & Chang, 2010; Volet, 2001; Volet & Järvelä, 2001). Järvelä et al. (2010) suggest integrating the individual and social (socio-emotional) aspects to better understand the impact of both the internal and external factors on self-regulation and motivation to learn. Järvelä and Volet (2004) argue that technology has added to the complexity of the issue of motivation, and at the same time, contributed to the creation of dynamic learning environments which promote deep learning, self-regulated learning and metacognition. With the emergence of sophisticated concepts such as *Computer Supported Collaborative Learning* (CSCL; Stahl, Koschmann, & Suthers, 2014) in the area of *Learning Sciences* (for more details see Sawyer, 2014b) as a specialised field of study, many researchers have shown interest in examining motivated learning in these complex learning environments. However, very few studies have been carried out to investigate the motivational effects of CSCL and ICT enhanced collaborative learning situations (Li et al., 2010). A report by Passey, Rogers, Machell, and McHugh (2004) described positive motivational impacts of ICT-based learning on students' motivation to learn and academic engagement. Järvelä et al. (2008) also reported more improvement in the learning goal orientations of students who worked collaboratively in face-to-face situations than those who worked in virtual groups using ICT. Another study by Järvelä and Järvenoja (2011) examines the process of students' socially constructed motivation regulation in collaborative learning tasks by studying the types of challenges students face and types of strategies they apply to overcome these challenges. Järvelä and Järvenoja (2011) suggest that motivation regulation should be considered as socially constructed (externally regulated) as the group influences individual motivation through task structuring, interest enhancement, efficacy management, social re-enforcing and socially shared goal-oriented talk. This study also aims to examine secondary students' motivation towards science learning in CSCL (face-to-face) classroom situations and is situated in science learning activities.

2.3.1. Motivation to learn science

Motivation to learn can be considered as a general academic or a situation/domain specific trait (O. Lee & Brophy, 1996). The domain specific motivation to learn, according to Brophy (1987) can be understood in the form of engagement in the learning activity. The engagement in a specific domain (for example science) is affected by students' motivational beliefs and cognitions about the domain (Boekaerts, 2010; Schunk et al., 2008). Students' motivational beliefs and thoughts consists of their knowledge, capability to learn the content, outcome expectancy, the purpose of the learning activity, intrinsic and affective task value and perceived attributions for success and failure. Boekaerts (2010) labels these thoughts as "meta-motivation" (p. 94), because use and functioning of these in a learning domain enables students to give meanings to learning activities. These beliefs, in other words, enhance engagement and make the learning meaningful. Engagement in a task is generally informed by the intention or goal of mastering the knowledge and skills that the learning activity intends to promote (Brophy, 1987; O. Lee & Brophy, 1996). Given that a common goal of science education in the 21st century is to understand scientific concepts at a conceptual level, to see connections with other concepts, subjects and daily-life, and to apply this understanding to solve science related problems (Konicek-Moran & Keeley, 2015; National Research Council, 2012b), motivation to learn science can promote this goal and intention to make science learning meaningful.

Lee and Brophy (1996) integrated the construct of motivation to learn with the cognitive and constructivist aspects (such as the cognitive processes of conceptual change) in science learning. From a cognitive view, students generally learn science by making meaning of the information, developing diverse beliefs, comparing their prior knowledge with established scientific knowledge; reorganising knowledge through conceptual change, cognitive dissonance, transforming and changing alternative conceptions; and finally, if needed, completely restructuring the knowledge (Duit & Treagust, 2003; Howe, Devine, & Taylor Tavares, 2013). From a constructivist view, learners actively construct meanings, make sense of the information and transform their understandings (prior knowledge) in the light of scientifically valid knowledge with an intention to understand scientific concepts. From a motivated learning point of view, students make sense of and understand the science concepts when they value science and adopt active learning strategies with the intention to master scientific knowledge and skills (Brophy, 2010b). By integrating the motivation to learn framework as described in the previous section and cognitive processes of science learning, Lee and Brophy (1996) defined motivation to learn science as follows:

> When students engage in science tasks with the goal of achieving a better understanding of science and activate strategies for doing so [*... they are motivated to learn science*]. While engaging in academic tasks in science classrooms, motivated students use cognitive and metacognitive strategies to integrate personal knowledge with scientific knowledge through conceptual change, and apply scientific knowledge to make sense of the world around them. (p. 306)

Therefore, from this point of view, the intended goals (mastery or learning) and metacognitive strategies (to draw or construct meanings) are two basic requirements to motivate students to learn science with understanding. Depending upon the varying degrees of these intentions, goals and activation of metacognitive strategies, students may show different motivational patterns about science learning (O. Lee & Brophy, 1996). Consistent with the views of Boekaerts (2002), Brophy (2010b) and Wentzel (2009), Shumow and Schmidt (2014) advocate that science teachers can make science learning meaningful by making the value of science learning explicit, and by promoting the value and relevance of science to students' everyday lives.

From time to time many researchers have examined different motivational constructs related to science learning. However, this number is smaller than those who have investigated cognitive and affective constructs (Vedder-Weiss & Fortus, 2011). Investigators such as Anderman and Young (1994), Anderson (2003), Koballa and Glynn (2007), O. Lee and Brophy (1996), Meece et al. (2006), Osborne, Simon, and Collins (2003), Tuan, Chin, and Shieh (2005), Vedder-Weiss and Fortus (2011), and Velayutham, Aldridge, and Fraser (2011) have studied the effects of motivational constructs such as attitudes, self-efficacy, goal orientations, utility value, intrinsic task-value and strategy use on student' performance, engagement and understanding in science. The majority of the research findings reported positive effects of these motivational constructs on science learning and engagement (Koballa & Glynn, 2007). For example, a study by Jackman, Townsend, and Hamilton (2008) report a significant gain in mastery goal orientations (that is, transformed from performance to mastery orientation), through increased self-efficacy and value for science learning, and all of these together enhanced science understanding and achievement. Koballa and Glynn (2007) suggest that high levels of self-efficacy and self-determination help students to accept challenges, set higher goals, expend greater effort, persist longer and use active learning strategies. Based on these empirical investigations some researchers (such as Glynn, Taasoobshirazi, & Brickman, 2009; Tuan et al., 2005; Velayutham et al., 2011) have developed instruments to examine students motivation to learn science in different contexts. The *Students' Motivation Towards Science Learning* (SMTSL) questionnaire developed by Tuan et al. (2005) is used in this study to measure Indian secondary school students' motivation towards science learning. The SMTSL assesses six motivational constructs: self-efficacy, science learning value, performance goal, achievement goal, active learning strategies, and learning environment stimulations. In relation to motivation towards science learning, the value of the content, self-efficacy, learning and performance goals, use of active learning strategies and stimulation of the classroom learning environment are the factors that need to be developed and examined (Tuan et al., 2005).

2.3.2. An operational definition of motivation to learn science

In relation to this study, motivation to learn science may be defined as the process through which students choose to learn and understand science, keeping in mind their goals (immediate as well as long-term career goals); understand and appreciate value of science learning; engage in science understanding with an intention to satisfy their curiosity and meet other cognitive and affective needs (self-efficacy, self-worth, self-determination); adopt active learning strategies; regulate their learning; help each other and seek help when needed; feel included ; show persistence in case of difficulties; and try to achieve the ultimate aim of understanding complex and abstract science concepts.

Given one of the chief purposes of education is to teach young people to find pleasure in the right things (Plato; cited in Peterson (2006)), effective science education should strive to enhance students' scientific literacy, understanding of abstract and essential concepts, enable them to apply the scientific knowledge and understanding to make their and others' life joyful, and transform them in to lifelong learners equipped with important scientific skills (National Research Council, 2012a, 2012b). The relation between science learning and motivation is perceived in the sense that motivation towards science learning helps in achieving the intended learning outcomes of understanding science and developing scientific literacy and skills.

2.4. Meaningful learning

As discussed in the previous sections, motivation to learn science can promote scientific attitudes, literacy and skills, it also can make science learning a meaningful experience for students (O. Lee & Brophy, 1996). According to Good and Brophy (1990), meaningful learning is a type of learning that develops specific skills, promotes critical thinking, develops problem solving skills, makes learning individual and enables students to transfer knowledge and skills between different learning contexts. Darling-Hammond (2008b) labels this kind of learning as *powerful learning*. Darling-Hammond argues that powerful learning can help in mastery of the fast expanding knowledge and development of requisite skills in order to meet the needs of increasingly complex and constantly changing work and learning environments. Darling-Hammond (2008b) stresses the development of *learning with understanding*, paraphrasing *the genuine right to learn* for all students in relation to *No Child Left Behind* Act (US Department of Education, 2004). Darling-Hammond (2008b) therefore, suggests transforming learning goals, teaching and learning, and assessment strategies according to the changing demands. Teaching and learning for understanding enables learners to develop the desired knowledge and skills, use and transfer knowledge in novel ways, critically defend and evaluate their ideas using reasoning and evidence, use innovative strategies to solve problems, showcase meaningful learning and understand the criteria that evaluates their learning (Darling-Hammond, 2008a). Darling-Hammond (2008a) suggests some strategies to engage students in meaningful learning: active, in-depth learning; authentic, formative assessment; collaboration opportunities; attention to prior knowledge and development; organising knowledge around core concepts and connections; and the development of meta-cognitive skills. Aligned with the *How People Learn* (HPL) framework (National Research Council, 2000b), Darling-Hammond (2008a) therefore recommends making learning environments *student-centered*, *knowledge-centered*, *assessment-centered* and *community-centered* for schools to promote meaningful learning.

According to Ausubel (2000), meaningful learning takes place when a learner is able to relate new information, concepts and propositions to existing ideas in his/her cognitive structure. Meaningful learning is different from rote memorisation of information, where little or no interaction/association is found between the new and existing knowledge stored in the mind. Ausubel (2000) states that one of the goals of education is to promote the transfer of knowledge and skills across learning situations. Mintzes et al. (2000) also affirm the fundamental goal of education as to facilitate learning through shared meaning between teacher and student. This shared meaning lies at the heart of the interaction between teacher and learner regardless of the subject matter, context or teaching methods (Mintzes et al., 2000). It is assumed that teachers and learners must work together to construct knowledge and negotiate meaning. In this way, students play an active role in knowledge construction and meaning generation, leading to meaningful learning. Therefore, meaningful learning is very important to construct new knowledge and to evaluate and restructure prevailing knowledge, and to make overall learning effective (R E Mayer, 2002).

Brophy (2010b) describes the nature of learning with understanding from a motivational perspective such that:

> The notion of learning with understanding, appreciation, and attention to life applications implies much more than mere interest in a topic and it includes cognitive strategies and metacognitive control components along with affective components. It requires activating a network of related schemas—clusters of insights, skills, values, and dispositions- that enable students to understand what it means to engage in school activities with the intention of accomplishing their learning goals and with the awareness of strategies they use in attempting to do so. (p. 220)

From this perspective, a motivated learner is one who seeks to understand something, sets learning goals, develops positive attitudes and dispositions, develops cognitive and meta-cognitive strategies to monitor their learning, and evaluates the process to ensure the achievement of their intended goals. Therefore, due to the inclusion of these cognitive and affective aspects, the concept of learning with understanding is, although similar to motivation to learn, more important than either intrinsic interest or extrinsic motivation (Brophy, 2010b). Shumow and Schmidt (2014) also comment that teachers' understanding of students' motivational states can help them to design a "classroom environment and create a learning community in which students and teachers are highly motivated to engage in activity that shapes meaningful learning" (p. 9). Given the relevant and personal nature of meaningful learning, it seems obvious that students will be motivated to learn for understanding.

In relation to science learning, the ultimate goal of science education is to organise teaching and learning in a way that produces complete understanding of scientific concepts (Konicek-Moran & Keeley, 2015; Mintzes et al., 2005). Zimmerman and Stage (2008) describe the nature of science learning from a layman's perspective as memorisation of facts, theories and laws, mechanical ways of hypothesis testing using scientific methods, drawing conclusions, making generalisations and making models to explain scientific phenomena. Conversely, Zimmerman and Stage (2008) argue that "understanding science is more complex (and interesting!) than the way science is portrayed or experienced in many science classrooms" (p. 157). In line with the National Research Council (2007), Zimmerman and Stage (2008) suggest that deep understanding of science concepts requires acknowledging students' diverse prior knowledge, examining learning trajectories or progressions (development of learning and thinking over time), managing challenges (misconceptions and conceptual change), developing meta-cognitive skills, and promoting science investigation and discourse skills (productive discussions, dialogues, talk and argumentations). Some science education researchers (for example, Kang, 2007; Konicek-Moran & Keeley, 2015; Novak, 2002) label this special type of meaningful learning as *conceptual learning* or conceptual understanding. Conceptual learning is basically the process of developing scientifically valid knowledge which results from understanding science concepts and their relationships. In this thesis, the two terms: meaningful learning and conceptual learning are used interchangeably, however because of one of the objectives of the study, the term conceptual learning is used more frequently.

2.5. Strategies for meaningful learning

Darling-Hammond (2008b) suggests a *Tetrahedral Model of Learning* which describes the process of selection of a learning strategy for development of meaningful learning in terms of four edges of the tetrahedron: the nature of the *content* (material to be learned), characteristics of the *learner* (nature of the beliefs, knowledge, skills, attitudes and motivation that students bring to the learning situation), the intended *goals* of the learning activity (interest, fun, performance or mastery), and finally the *assessment* of the new learning in relation to the set goals. These four components can inform designing of an effective educational instruction to help students to learn and understand (Darling-Hammond, 2008b). Woolfolk (2014) states that effective learning strategies help students *learn how to learn* and can be taught, but they are rarely taught directly until high school or even college. According to Woolfolk (2014), in order to learn something, students must be attentive, focussed and cognitively engaged, willing to invest effort, process the information deeply by making connections, organise and reorganise thinking, and monitor and regulate their learning. A teacher's emphasis in the classroom should be on the development of "effective learning strategies and tactics that *focus attention and effort, process information deeply, and monitor understanding*" (Woolfolk, 2010, p. 272; emphasis in original). To distinguish learning *strategies* from learning *tactics*, Woolfolk (2010) states that a learning strategy is an overall plan of attack keeping in mind the achievement of intended learning goals, whereas learning tactics are the specific techniques which can be considered as different components of a plan or strategy. Therefore, Woolfolk (2010) suggests that students should be exposed, as well as trained, to use different learning strategies and tactics to make learning effective. Examples of some of the strategies are note taking, highlighting, summarizing, revising, making diagrams to map relations (mind and concept mapping), Jigsaw and the K-W-L strategy.

Some researchers use the terms strategy and intervention interchangeably. However, these differ in their nature and scope. An intervention is a technical term which appears to be more formal, specific and comprehensive, and is often problem, goal, plan and action oriented. In contrast, a strategy is a set of methods and/or activities and is less formal. An intervention may consist of many strategies but a strategy cannot always be considered as an intervention (Lee, 2015). The basic difference that Lee (2015) highlights is that an intervention is specifically aimed at a need or problem and is formal and monitored. This is in contrast to a strategy which is informal and is not always monitored. Therefore, an intervention is a systematic process of assessing the nature and cause of the problem/issue, and planning the procedure to be employed to remediate a social, political or educational problem.

An educational intervention, according to Wright (2012) is “a strategy used to teach a new skill, build fluency in a skill, or encourage a child to apply an existing skill to new situations or settings” (p. 3). Generally, an educational intervention is administered to students who experience learning difficulties or problems in a classroom. An educational intervention depends upon the identified need and can take many forms. These include helping students to manage their behaviour, time, classwork and home assignments as well as managing their communication and learning difficulties. In relation to learning problems such as conceptual learning, an educational or academic intervention can also be thought of “a set of actions that, when taken, have demonstrated ability to change a fixed educational [*learning*] trajectory” (Methe & Riley-Tillman, 2008, p. 37; emphasis added). Similarly, behaviour and motivation focused interventions can be designed and applied to address behavioural and emotional problems. According to Hulleman and Barron (2016), motivational interventions can be divided into two categories: targeted interventions and multicomponent/comprehensive motivation interventions. The targeted interventions specifically focus on one or a maximum of two components of motivation at a time and are shorter in duration. Examples of such interventions are goal-related, expectancy- and control-focused, and interest- and value-focused interventions. In contrast, comprehensive interventions integrate multiple motivation components to understand the comprehensive nature of the phenomena and are longer in duration. These interventions generally leverage motivation alongside the content and instructional strategies, such as collaborative learning to improve learning, to develop competencies and skills (Hulleman & Barron, 2016). An example of such a comprehensive intervention is the *Motivation and Engagement Wheel* designed by Andrew Martin (2008) which consists of the eleven aspects of the wheel targeted to students’ adaptive and maladaptive behaviours. The intervention designed and developed in this study is of a multicomponent type (see sections 2.6 and 2.7).

Many researchers have developed different strategies and interventions, depending upon their intentions and focus, which promote meaningful learning. Although the two terms ‘strategy’ and ‘intervention’ differ in scope and nature, both refer to the instructional procedures for teaching and learning that promote understanding. Given the focus on conceptual learning and motivation to learn (science) in this study, only those which meet the criteria of motivating students to learn and understand are briefly discussed in the following sections. Moreover, the main aim of describing these strategies is to give the reader an idea of some of the similar interventions in the field because one of the main goals of this study is to design a *motivated learning* intervention. Some of the cognitive and meta-cognitive interventions that can promote students' conceptual learning and motivation towards learning are described below.

Carole Ames (Ames, 1990, 1992) developed a very comprehensive classroom intervention- TARGET - based on goal theories of motivation to encourage students to focus on learning and help teachers to design motivational instruction. The acronym TARGET stands for the six components: Task, Authority, Recognition, Grouping, Evaluation, and Time. *Task* stands for the activities that students find engaging and interesting, *Authority* is the sharing of power and transfer of responsibility to students and *Recognition* is the appreciation and acknowledgement of the progress made by students in achieving a goal. *Grouping* stands for the process of managing collective situations in order to avoid comparison, encourage collaborations and minimise competition, self-*Evaluation* focuses upon using several methods to monitor the progress, and flexible use of *Time* is required, depending upon the difficulty level and value of the learning activity. Ames (1990) conducted an experimental study to compare at-risk TARGET intervention students with comparison group students. The findings revealed that the intervention students reported that their classrooms were more learning-oriented than the comparison group students. Ames (1990) also reported positive attitudes, favourable competence, learning strategy use and overall better intrinsic motivation shown by the intervention group students. In another study, Ames (1992) concluded that to design a comprehensive motivational learning intervention, practitioners should identify strategies and motivational principles to inform these six classroom structures, and produce exemplary practices respectively.

The K-W-L strategy was developed by Ogle (1986) as a teaching model to develop the active reading of texts in a cooperative situation. The three acronyms represent the three steps involved in the strategy: *Know Want* and *Learn*. Students work in small groups, and in relation to these acronyms, they focus their discussion around three questions: What do we already *know* about this concept? What do we *want* to know? And at the end of the reading (discussion), what have we *learn*ed? Students generally record this information on a chart which has three columns, one for each step. Therefore, in the first phase, students discuss the beliefs, opinions and conceptions that they already possess about the subject of discussion (prior knowledge). In the second phase they identify the learning goals and knowledge gaps and thus discuss the knowledge they need to lean. At the end of the reading, students discuss the important things and points they have learned from the learning activity and also reflect on what they still need to learn. Technically, K-W-L appears to be (and should be) a graphic organiser, like a concept map or mind map, which is used to organise knowledge.

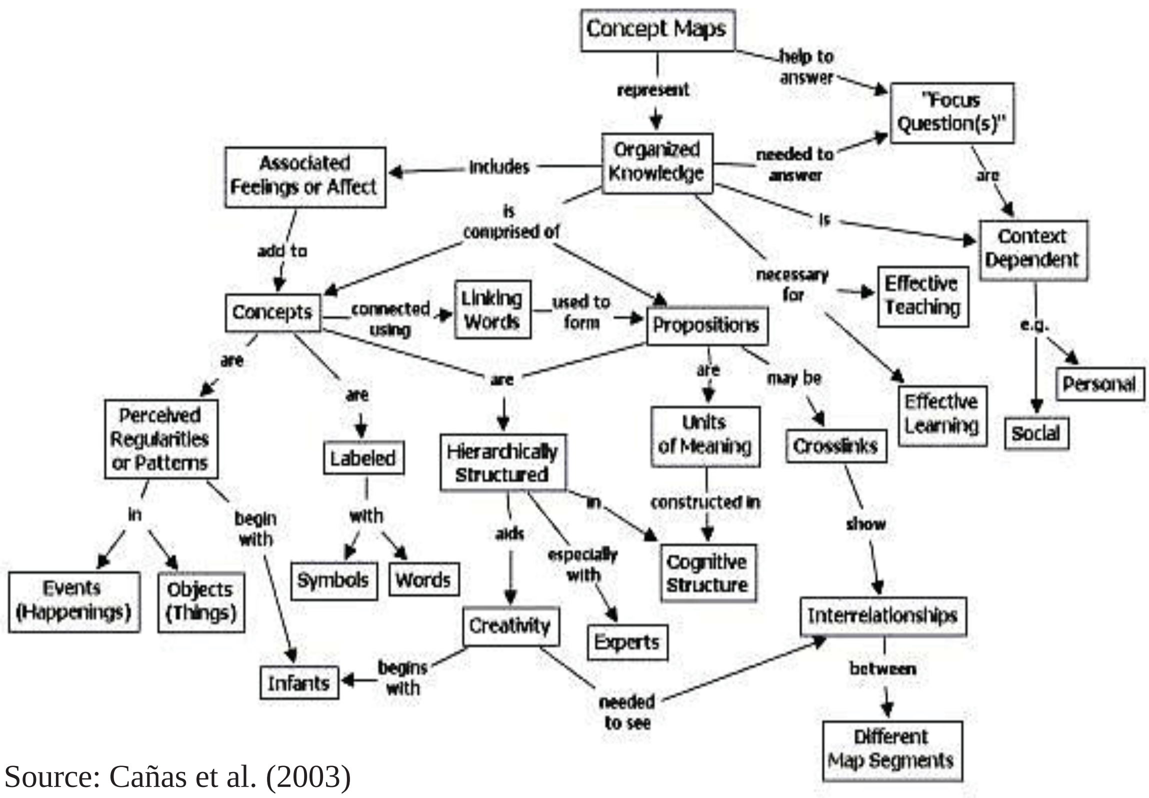
Another learning intervention named *Concept-Oriented Reading Instruction* (CORI) was designed by Guthrie, McRae, and Klauda (2007) with an aim to enhance students reading comprehension, engagement and motivation for reading. The design of the intervention is based on the motivation principles (see Pintrich, 2003) which encourage students to use learning strategies by integrating reading instruction in subject-related learning activities. In the CORI design, the five instructional practices of relevance, choice, success, collaboration, and thematic unit are integrated with motivational constructs such as interest, intrinsic motivation, task orientation and self-efficacy. The CORI intervention consists of four phases of instruction: observe and personalise; search and retrieve; comprehend and integrate; and communicate to others. The intervention has been reported to enhance intrinsic motivation and engagement in a number of studies in different subjects (Brophy, 2010b).

Some other strategies and interventions which have been empirically examined for effective learning and motivation to learn are: Student Teams-Achievement Divisions (STAD), Teams-Games-Tournament (TGT), Team-Assisted Individualisation (TAI), Jigsaw II, Project-based learning, and Motivation and Engagement Wheel (Martin, 2008). Some science related strategies which have been reported enhancing science learning are: *Knowledge Integration* (KI) perspective (Linn, 2006), *Exploratory Talk* (Mercer & Littleton, 2007), *Interthinking* (Littleton & Mercer, 2013), and *Educational Dialogues* (Mercer, 2008; Mercer, Dawes, & Staarman, 2009; Mercer & Howe, 2012). However, most of the science-related strategies have cognitive and meta-cognitive components and lack motivation components. In other words, the motivational aspects of learning interventions have been less frequently researched. To some extent, this research proposes to fill this gap by designing a motivational learning intervention. Some of these strategies which were integrated to design the intervention used in the study (see section 2.5.4 and 2.6) along with related literature are discussed in the following sections.

2.5.1. Concept mapping

Concept mapping (CM) is a visual cognitive instructional strategy that can be used to promote effective and meaningful learning (Cañas et al., 2003; Konicek-Moran & Keeley, 2015). Woolfolk (2014) defines a concept map as “a drawing that charts the relations among ideas” (p. 359). According to Novak and Cañas (2008), concept maps are graphical tools used for the representation and organization of knowledge. In a concept map, the main concepts are generally enclosed in boxes or circles linked with each other. An important aspect of a concept map is that the linking lines are labelled to make the relationships between concepts explicit. A label can be a single word, a group of words or a symbol that represents the word. The concepts (boxes/circles) are linked by some lines which show meaningful relationships in the form of propositions between the linked concepts. Propositions are two or more concept labels linked by words in a semantic unit (Novak & Gowin, 1984). A concept map can provide a kind of visual road map showing some of the pathways we may take to connect ideas or concepts and to represent our thinking in the form of a diagram. Therefore, concept mapping can be defined as the process of visual representation of relationships among concepts. Figure 2.1 shows a concept map which describes the meaning and nature of a concept map.

As seen from the figure 2.1, major and minor concepts are arranged in a hierarchy: the most general concept at the top and less general and more specific at the bottom of the map. The cross-links between the concepts indicate the relationship with which one concept in a domain of knowledge is linked with other concepts in different domains of knowledge. Descriptions and examples can also be inserted in a concept map to describe concepts and to clarify the relationships to make sense of the information presented. In modern computer-generated and interactive concept maps, some media such as objects, photos and video links, also can be inserted.



Source: Cañas et al. (2003)

Figure 2.1 A concept map that describes a concept map

2.5.1.1. Background and uses

Concept mapping as a learning strategy has its origin in research carried out by Joseph Novak and his associates at Cornell University in the 1970s. This research was carried out to study changes in students' understanding of science concepts over a period of a 12-year span of schooling (Novak, 1990). Working from Ausubel's assimilation theory, Novak and colleagues developed the idea of hierarchical representation of concept-propositional framework, which they later described as *cognitive map* or *concept map* (Novak, 1990). According to Ausubel's (2000) assimilation theory, the assimilation of new concepts and propositions with a person's already existing concept and propositional framework results in effective learning. An individual's knowledge framework, also called cognitive structure, is organised hierarchically, and most new learning occurs through derivative or correlative acquiring of new concept meanings under an existing concept-propositional framework.

Concept maps have been used as a teaching and learning strategy in almost all science subjects. Novak (1990) started using concept maps as an effective tool in science education for meaningful learning, and later their use was extended to other science subjects by other researchers. For example, researchers like Buntting (2006) and Kinchin (2000) in biology; Greene (2011) in earth sciences; Francisco, Nakhleh, Nurrenbern and Miller (2002) in chemistry; Roth (1994), Roth and Roychoudhury (1994) in physics; Akinsanya and Williams (2004) and Wheeler and Collins (2003) in nursing; and West, Park, Pomeroy, and Sandoval (2002) in medical sciences examined their effectiveness as teaching and learning tools from different aspects and at different stages of education. As a teaching and learning method, concept mapping has been reported to promote effective learning by most of the research studies (Adesope & Nesbit, 2010; Cañas et al., 2003; Novak, 2010).

Concept maps have also been used as an assessment tool in different subjects to assess students' conceptual learning, validity of knowledge and to locate misconceptions (Edmondson, 2000). Many researchers (for instance, Beaudry & Wilson, 2010; T. E. Johnson, Ifenthanler, Pirnay-Dummer, & Spector, 2010; Vodovozov & Raud, 2015) have discussed the important potential of concept mapping for assessing students' learning. The report by Cañas et al. (2003) mentions concept maps as a powerful evaluation tool to assess both the valid and invalid knowledge held by students. Concept mapping can be used in formative as well as summative assessments (Kinchin, Hay, & Adams, 2000). In the form of a formative assessment tool, a concept map can make students' thinking visible, indicate the knowledge gaps, show the learning progress and help diagnose and monitor learning. As a summative assessment tool, concept maps can be used to examine a student's final understanding of the concept or content and the level of knowledge processing and thinking in terms of valid and invalid linkages on the constructed map.

2.5.1.2. Concept mapping and meaningful learning

Concept mapping is an important tool that can help students to learn meaningfully (Cañas et al., 2003). According to Novak (2010) concept mapping plays a key role in learning, helping students to take charge of their own meaning-making. Concept mapping supports students to organize their thoughts and knowledge about a given concept or topic in relation to their prior knowledge. It encourages divergent and reflective thinking, and focuses student attention on identifying and labelling relationships between key concepts (Novak, 2010). In this way, concept mapping can play an important role in the enhancement of meaningful learning of students

(Akinsanya & Williams, 2004; All & Havens, 1997; Heinze-Fry & Novak, 1990; Kinchin, 2000; Mason, 1992; Novak, 1990, 2002, 2010; Novak & Cañas, 2008). According to Novak (2010), concept mapping also provides a mechanism for students to present their knowledge and make it visible. Therefore, it can prove to be a useful diagnostic tool for teachers if the existing knowledge of students is faulty or incomplete. This way, concept mapping can also help teachers in becoming more effective teachers (Cañas et al., 2003).

Greene (2011) conducted an experimental study to examine the effect of learning through concept mapping on the science achievement of third grade students. The findings revealed a significant difference in participants' test scores by time and group in pre-post and experimental-control group settings. The results also indicated a significant difference, within the subjects' main effect across time, and between the subjects' main effect by group. Therefore, the study reported concept mapping as a teaching-learning strategy that could enhance students' conceptual learning and science achievement.

Soong (2010) examined the effectiveness of concept mapping intervention on secondary students' physics revision and conceptual learning of physics concepts. The intervention, *Computer-mediated Peer Discussion and Prescriptive Tutoring* was designed for students to learn physics content in groups using computers. The teacher-led prescriptive tutoring part of the intervention was focussed particularly on the identification and correction of misconceptions. The results of the experimental study revealed the concept mapping intervention to be effective in physics revision and enhancing students' conceptual learning and achievement.

In a study carried out by Buntting (2006) to investigate faculty assumptions of students' prior knowledge and effectiveness of concept mapping interventions, students in interviews reported that concept mapping helped them to identify links between different concepts and learn the content meaningfully. Most of the students used the concept mapping intervention in other tutorial classes and courses of study. They also reported that concept mapping enhanced learning for test questions that required understanding of links between concepts, whereas no significant difference was reported in the case of test items requiring simple recall of facts. It was concluded that concept mapping promoted deep learning, but an issue of consistency between the type of learning specified by faculty in course objectives and deep learning encouraged through the use of concept mapping was raised by the study.

Walrond (2004) conducted a case study of four grade 7 and grade 8 students, to investigate the effectiveness of integrating the use of concept mapping using the computer software *Inspiration* into a cooperative inquiry unit. The results indicated higher-order learning (metacognitive in nature) outcomes as a result of integrating concept mapping with cooperative learning. Students used concept maps as mind tools and critical thinking was reported as being enhanced through concept mapping. The case study group revealed a positive impact of co-operative concept mapping on learning and thinking.

In a study, Kinchin (2000) argues against a rigid and didactic presentation of curriculum that fails to respect a student's perspective. Kinchin (2000) puts emphasis on the development of student-teacher dialogue to promote meaningful learning while using concept mapping. Kinchin also suggests teachers integrate students' beliefs to transform their teaching practices, and argues that this is only possible when teachers question their own beliefs and approaches to teaching and learning. Kinchin also concludes that quantitative methods of concept map analysis are inappropriate for promoting meaningful learning among secondary school science teachers and their students due to various reasons. Consequently, Kinchin (2000) developed a qualitative approach to analyse concept maps. Kinchin also suggests that constructivist classroom approaches can be mediated by concept mapping.

Jegede, Alaiyemola and Okebukola (1990) reported that concept mapping, as a meta-cognitive strategy, can enhance learning by assisting learners in understanding the concepts and relationships between them. Concept maps can develop meta-learning and thinking and can be used as meta-knowledge tools to empower learners. With the help of concept mapping, a learner can take charge of their learning in a highly meaningful way. The authors concluded that concept mapping promoted meaningful learning and achievement in biology, and that it also depressed the anxiety of learners.

Furthermore, Hattie's (2009) meta-analysis results for concept mapping (impact on students' achievement) report an effect size (*d*) of 0.57, which is a desired effect to have an impact on students' achievement. Concept mapping as a teaching strategy when compared to other forms of teaching, such as lecturing or discussion, showed an effect size (*d*) of 0.74. Additionally, another meta-analysis by Nesbit and Adesope (2006) also reported larger effects of concept mapping when students constructed concept maps (*d* = 0.81) as compared to when students studied using teacher-made concept maps (*d* = 0.37). Nesbit and Adesope (2006) concluded that the high achievement gains were the result of higher student engagement and positive attitudes when students constructed their own concept maps. The results from Nesbit and Adesope study indicate that concept mapping can also enhance students' motivation. Therefore, all the above mentioned research studies demonstrate the positive effect that concept mapping can have on students' meaningful learning and science achievement.

2.5.1.3. Perceptions about and experiences of concept mapping use

Some studies (for instance, Kilic, Keleş, & Sağlam, 2012; Roth, 1994; Taskin, Pepe, Taskin, Gevat, & Taskin, 2011) have investigated students' and teachers' views about concept mapping and most of them reported positive views about their use in classroom learning environments. A meta-analysis by Nesbit and Adesope (2006) of 55 studies found that in addition to the improved retention and transfer of knowledge, students in most of the studies also reported positive attitudes toward learning with concept maps. Another meta-analysis of 19 studies carried out by Horton et al. (1993) also found mostly positive experiences reported by students and teachers who used concept mapping. Consistent with these meta analyses, a research study by Buntting (2006), affirmed the positive attitudes shown by both teachers and students towards the use of concept mapping in their classes.

Trehan (2015) examined the experiences of undergraduate introductory students to whom concept mapping was presented as a teaching and learning strategy. This study explored in detail the experiences of students and the impact of concept mapping use on students' perceptions of their ability to relate and apply different key statistical concepts. The findings reported a mix of experiences: positive, negative and neutral, about the use of concept mapping. Students perceived that their ability to integrate statistics concepts was enhanced as a result of concept mapping use. However, students reported unfavourable results in relation to the impact of concept mapping use on statistics problem solving. With regard to the positive experiences of concept mapping use, students perceived improved understanding of concepts and highlighted meta-cognitive benefits, such as the identification of gaps in their knowledge and being able to monitor their learning progress. Students also perceived concept mapping to be a valuable tool to help learning transfer and facilitate training in other fields and daily life. Students who reported negative experiences perceived concept mapping as a waste of time, reported being unmotivated to attend classes and expend extra efforts, demonstrated resistance to use of the strategy and preferred the usual teaching and learning methods. Some students perceived no substantial influence on their statistics learning and reported that concept mapping did not necessarily enhance their conceptual understanding. Some students perceived concept mapping a tool to create products (assignments) for external assessment rather than a strategy for meaningful learning. These students reported concept mapping use as an extra add-on to their usual learning and found it not particularly helpful.

Another study by Abu Askar (2013) investigated the views of university students about the use of concept mapping in their learning. The findings of the study revealed that concept mapping was a useful tool for international students' learning in the university. Although concept mapping has elsewhere been shown to promote the development of critical thinking and creative thinking skills, the study reported that concept mapping itself did not develop these skills.

Kilic et al. (2012) examined elementary teachers' perceptions of concept mapping use in their classroom teaching. The results of the investigation suggested that these elementary teachers found concept mapping useful, and that it was effective for teaching and learning. Teachers perceived concept mapping as a practical tool to organise knowledge and an important instrument to provide feedback to students. The study suggested the need for teachers to train students about how to construct effective maps, for teachers to learn how to integrate concept mapping with their teaching practices and how to effectively use concept mapping as an assessment strategy. Another study investigating secondary teachers' perceptions of concept mapping was carried out by Mutodi and Chigonga (2016). They also echoed the findings of studies that found concept mapping to be useful, effective and practical strategy for teaching mathematics and providing feedback to students. Other important findings were that concept mapping was perceived to be helpful in representing and organising knowledge, in recalling and retaining information and that it was a valuable tool for formative assessments.

A study by Herring (2007) explored year seven students'(aged 12-13), teachers' and teacher librarians' views about the use of concept mapping and students' ability of skill transfer across subjects and across time. A minority of students, who were actively engaged in the use of concept mapping, perceived it as a useful strategy and reported concept mapping to be helpful in transferring their developed skills across subjects. The majority of students, who were not actively engaged to the required degree, reported the use of concept mapping as valuable but reported unlikely to transfer the skills gained to other subjects. There were still a few students who struggled to learn and use concept mapping in their learning and reported positive attitudes however reported almost nil transfer of skills. Findings from the Herring (2007) study also suggested that transfer of skills was found to be a complex process.

Therefore, most of the studies carried investigating the effect of concept mapping, whether individual or collaborative (group) maps, student made or teacher made, computer-based or paper-pencil-based, and face-to-face or virtual mode, report positive attitudes, positive experiences, however somewhat differing perceptions about the concept mapping use (in general) in teaching and learning.

Although there are numerous studies reporting views and experiences of students, teachers and others concerned with teaching and learning in relation to concept mapping use, very few have reported the factors that could enhance or impede concept mapping use in science classrooms. Trehan (2015) reported that students' ability to integrate new ideas into their existing knowledge was an important enabler for students. The resulting deeper understanding and motivation were also seen an enabler to the optimum use of concept mapping. The provision of keywords and appropriate linking words by the teacher also promoted effective concept mapping use. It should be noted however that when students lack understanding of the relationships between concepts and struggle to find the appropriate linking words, this can be a barrier to effective concept mapping use (Trehan, 2015).

Another study by Abu Askar (2013) reported that the participants' previous training of concept map construction could be seen as a challenge or barrier to concept mapping use. For instance, a student is likely to construct an effective concept map if he/she has some experience in drawing some knowledge organiser such as a mind map. In the case of computer generated maps students reported the internet connection was another challenge. The internet connection was needed to download some media such as photos or diagrams to make concept maps effective and better. Other perceived barriers in the effective use of concept mapping in the Abu Askar (2013) study were the cost of the software, the language of the software, and lack of computer literacy and skills. Collaborative concept mapping was reported as an enabler to develop critical thinking and creative thinking skills in the Abu Askar research. Kilic et al. (2012) also noted some difficulties faced by elementary teachers while constructing concept maps. The majority of teachers reported difficulties in determining major and minor concepts, finding appropriate relationships and setting up the hierarchy, whereas a small number of teachers found it difficult to use linking words and adapt the concept maps to students' levels. The research by Herring (2007) reported a lack of a 'culture of transfer' (transfer of concept mapping skills across subjects and new situations) among students as a major challenge in using concept mapping.

A very small number of studies have specifically investigated the motivational aspects of concept mapping and collaborative concept mapping (CCM) use. Some studies (for example, Novak, Gowin, & Johansen, 1983) have emphasised the importance of motivational factors and have suggested examining how these factors impact the process of teaching and learning using CCM. One recent study by Haugwitz, Nesbit, and Sandmann (2010) has examined some constructs of motivation (cognitive ability and instructional efficacy) and reported that the strategy enhanced the post-test scores for the students whose cognitive ability was below the median for the sample. Hughwitz et al. therefore recommended using CCM with students at all levels of cognitive ability.

2.5.2. Collaborative concept mapping

2.5.2.1. Collaborative learning

Collaborative learning is a situation in which two or more people learn or attempt to learn something together (Dillenbourg, 1999). It is a strategy in which students make intellectual efforts to solve a problem, complete a task, or create a product together in a group. According to social constructivists, learning should involve interaction with other people or environments which foster potential development through the instructor's guidance or in collaboration with more capable peers. Gokhale (1995) defines collaborative learning as:

> An instruction method in which students at various performance levels work together in small groups toward a common goal. The students are responsible for one another's learning as well as their own. Thus, the success of one student helps other students to be successful. (p. 1)

The members of a group have a common goal; members show responsibility for supporting each other and the group as a whole. Social constructivism provides a theoretical framework for collaborative learning (Bruffee, 1998; Chaka, 2010; Soller & Lesgold, 2007). Sociocultural theory emphasises the important role played by interactions and relationships in collaborative learning. In relation to collaborative science learning, Glasgow, Cheyne, and Yerrick (2010) affirm that "peer review, collaborative effort, and argumentation are the gold currency of scientific discourse and process" (p. 74) and thus recommend teaching the collaborative strategies and skills to science students.

A report by the Committee on Increasing High School Students' Motivation to Learn (National Research Council and the Institute of Medicine, 2004) concludes that when students work in collaboration, they take up challenging tasks and develop self-regulation and many other important social and cognitive skills. The committee added:

> Collaborative work also can help students develop skills in cooperation. Furthermore, it helps create a community of learners who have responsibility for each-others' learning, rather than a competitive environment, which is alienating to many students, particularly those who do not perform as well as their classmates. (p. 51)

Therefore, collaborative learning helps to create a cooperative learning environment that promotes trust, confidence and responsibility and reduces competition among the group members. These collaborative learning environments can utilise some specific strategies, for instance Thinking Together (Littleton & Mercer, 2013; Mercer & Littleton, 2007), Exploratory Talk (Mercer, 2010; Mercer & Littleton, 2007), Educational Dialogues (Littleton & Howe, 2010) and Argumentation (Osborne, 2010; Osborne, Simon, Christodoulou, Howell-Richardson, & Richardson, 2013), to leverage the additional benefits of these strategies.

Research evidence suggests that collaborative learning has positive effects on students' learning, achievement and motivation (Wentzel, 2005a, 2005b; Wentzel & Watkins, 2011; Wentzel & Wigfield, 1998). In his meta-analysis which measured the impact of a range of strategies and interventions on achievement, Hattie (2009) reports an average effect size of 0.49 for collaborative learning. However, Hattie (2009) suggests that to ensure maximum effects from a group activity, the group should be small, students should have good training and experience in the strategy, the instructional material should be adapted according to the psychological level of students and diverse levels of ability should be acknowledged while designing group instruction. Many research studies (for example, Baker, Andriessen, & Järvelä, 2013; Chaka, 2010; Felton, Garcia-Mila, Villarroel, & Gilabert, 2015; Kwon, 2006; Srinivas, 2011; Watkins, 2009; Wentzel & Watkins, 2002) have reported the learning benefits of collaborative learning. Collaborative peer learning and group learning also has a positive impact on relationships and motivation (Wentzel & Brophy, 2014; Wentzel & Watkins, 2011).

2.5.2.2. Rationale for collaborative concept mapping

Collaborative learning is a strategy based on social constructivist theory to enhance meaningful learning (Chaka, 2010; Dillenbourg, 1999) and critical thinking (Gokhale, 1995). Concept mapping is another strategy used for conceptual and meaningful learning in science (Akinsanya & Williams, 2004; All & Havens, 1997; Heinze-Fry & Novak, 1990; Kinchin, 2000; Mason, 1992; Novak, 1990, 2010; Novak & Cañas, 2008). Each of the two strategies has proven benefits associated with it and research suggests that if combined, these two strategies can motivate students to learn conceptually and meaningfully (Cañas et al., 2003; Chaka, 2010; Haugwitz et al., 2010; Kinchin, 2000; Kinchin, De-Leij, & Hay, 2005; Konicek-Moran & Keeley, 2015; Stoyanova & Kommers, 2002). According to Vélez-Ibáñez and Greenberg (1992), students bring to the classroom a variety of *funds of knowledge* (experiences, beliefs, understandings and misunderstandings). There are some strategies which can utilize these diverse funds of knowledge for effective learning. Collaborative concept mapping (CCM) is one such effective and useful strategy which enhances meaningful learning and where students can build upon one another's knowledge (Adesope & Nesbit, 2010; Basque & Lavoie, 2006; Chaka, 2010; Kinchin, 2000; Kinchin et al., 2005; X. Liu, 2004; Nesbit & Adesope, 2006; Okebukola, 1992).

Research evidence suggests that in some school subjects, for instance Science and Mathematics, there is scope for generating misconceptions in students' minds (Cañas et al., 2003; Greene, 2011; Kinchin et al., 2005; Novak, 1990; Roth & Roychoudhury, 1994; Woolfolk, 2014). Accordingly, these subjects require higher cognitive skills and some specific strategies to clear these misconceptions. Collaborative learning, as the latest research indicates, has potential for enhancing meaningful learning by supporting cognitive conflict, restructuring and conceptual change processes (Mintzes et al., 2000; Novak, 2010; Roth & Roychoudhury, 1994; Ruiz-Primo & Shavelson, 1996; Sampson & Clark, 2009; van Boxtel, van der Linden, Roelofs, & Erkens, 2002; Woolfolk, 2014). Therefore, collaborative concept mapping (CCM) can prove to be an effective instructional strategy in science to enhance meaningful learning along with clarification of misconceptions.

2.5.2.3. Research on collaborative concept mapping

Many studies have been conducted to investigate the effect of collaborative concept mapping (CCM) as a learning and teaching strategy on students' effective and meaningful learning (for example meta-analysis by Adesope & Nesbit, 2010; Nesbit & Adesope, 2006). Different studies have specified different theoretical frameworks for the use of CCM. However, most of these draw on the sociocultural and socio-cognitive theories while some others specify situated learning, symbolic interactionism, distributed cognition and some special cases of socio-cognitive theories, such as cognition conflict or dissonance as well as cognitive flexibility theory (Basque & Lavoie, 2006; Basque & Pudelko, 2010).

Most of the studies have concluded that CCM promotes conceptual and meaningful learning (for example, Adesope & Nesbit, 2010; All & Havens, 1997; Basque & Lavoie, 2006; Basque & Pudelko, 2010; Chaka, 2010; Gaines & Shaw, 1995, October; Haugwitz et al., 2010; Heinze-Fry & Novak, 1990; Irvine, 1995; Jang, 2010; Kang & Howren, 2004; Kinchin, 2000; Kinchin et al., 2000; Markham, Mintzes, & Jones, 1994; Mintzes et al., 2000; Roth & Roychoudhury, 1993, 1994; van Boxtel et al., 2002). A meta-analysis by Horton et al. (1993) investigating the effectiveness of concept mapping as an instructional tool revealed enhancement in students' achievement and attitudes. Some other studies (for instance, D. S. Brown, 2003; Greene, 2011; Kern & Crippen, 2008; Romance & Vitale, 1999) have also found that CCM enhances science achievement and promotes robust conceptual understanding.

Roth and Roychoudhury (1994) describe CCM as a tool for social thinking that engages both students and teachers in science discourse. Therefore, CCM also has potential to enhance higher order cognitive and critical thinking skills of students in collaborative situations (Basque & Lavoie, 2006; Basque & Pudelko, 2010; Sampson & Clark, 2009; Walrond, 2004; Wheeler & Collins, 2003). Cañas et al. (2003) and Novak (2010) also emphasise the important role played by CCM in improving students' skills, knowledge and motivation to learn. Liu (2004) investigated the effects of concept mapping to assess relational conceptual change in science and concluded that CCM was able to account for student conceptual change in ontological, epistemological, and social/affective domains. The two main meta-analyses (Adesope & Nesbit, 2010; Nesbit & Adesope, 2006) related to the collaborative use of concept mapping also confirmed the positive impacts of CCM on learning and achievement.

2.5.3. Computer-based concept mapping

Computer-based instruction is a method of delivering instruction with the help of a computer in a classroom or any other learning situation. Instruction, according to Smaldino, Lowther and Russell (2012) means, "deliberate arrangement of experience(s) to help learners achieve a desirable change in performance; the management of learning, which in education is primarily the function of the teacher" (p. 311). Smaldino et al. (2012), defines computer-assisted instruction (CAI) as "instruction delivered directly to learners by allowing them to interact with lessons programmed into the computer system" (p. 310). Therefore, computer-based teaching and learning can be seen as a teachers' management of computer resources to organise the learning activities and experiences for students for the maximum benefits. While using CAI in education, a program is installed on the computer to teach and direct the activities of learners which are intended toward acquisition of knowledge and skills (Jonassen, 2000). This method of delivering information can be comprised of different strategies, such as drill and practice, tutorials, computer games, simulations, problem solving and other computer applications as well as the use of the internet. These strategies make use of different media of instruction such as text, audio, visual, video, hypermedia and interactive media (Smaldino et al., 2012).

Computer-assisted instruction (CAI) is an important instructional strategy to promote meaningful learning (Kulik, Kulik, & Bangert-Drowns, 1985; Ozmen, 2008; Yalcin & Celikler, 2011; Yesilyurt, 2010, 2011; Yusuf & Afolabi, 2010). Smaldino et al. (2012) argue that computer-assisted instruction is ‘a must’ for the organisation of learning and teaching in 21st century, which is dominated by technology. Serin (2011) and Soong (2010) investigated the effects of computer-based concept mapping interventions on the achievement and problem-solving skills of science students and reported a statistically significant increase for both variables. However, this enhancement was not ascribed purely to the technology used. Many research studies have compared computer-assisted instruction as a supplement to traditional instruction and concluded higher achievement with computer-assisted instruction than with traditional methods alone (Cotton, 1991). Most of the studies have been conducted to investigate the effects of computer-assisted instruction on achievement and learning. Other studies have reported the effects of computer-assisted instruction on thinking, retention, rate of learning, motivation, problem solving and attitudes towards learning.

Serin (2011) investigated the effects of computer-based instruction on achievement and problem solving skills of science and technology students and reported a statistically significant increase in both variables. Similar results in relation to the achievement were also reported by Kara and Kahraman (2008), Yesilyurt (2011) and Soong (2010) in secondary school physics; Yusuf and Afolabi (2010) in relation to performance and achievement in secondary school biology; Yesilyurt (2010) in science and mathematics; Yalcin and Celikler (2011) in science; Ozmen (2008) in chemistry achievement; and Basturk (2005) in introductory statistics. Some studies (e.g., Owusu, Monney, Appiah, & Wilmot, 2010) have reported converse effects i.e. in favour of traditional lecturing methods. But when interviewed, students in the Owusu et al. (2010) study reported CAI to be more interesting than traditional lecture methods.

Most of the studies have reported CAI to be effective in enhancing learning. For instance, Soong (2010) concluded that a CAI intervention was effective to promote improved learning outcomes. Other studies, for example, Ozmen (2008) reported enhanced conceptual learning associated with CAI, while Yalcin and Celikler (2011) concluded that CAI resulted in permanent learning for secondary school science students. Some of the meta-analysis conducted by Yesilyurt (2010, 2011) and Kulik et al. (1985) have also reported that CAI was effective in most of the studies.

Smaldino et al. (2012) state that the classrooms can be thought of on a continuum extending from no use of technology (traditional) to optimum use of technology (digital). According to Angeli and Valanides (2009), technology is not to be considered as a delivery vehicle but as a *cognitive partner* to amplify and augment student learning in a classroom. Contrary to Angeli and Valanides's (2009) suggestion, this research has considered and used computer as a delivery medium of the concept mapping to organise teaching and learning, yet this does not deny the possibility of any cognitive or affective gains due to the computer-based instruction use.

2.5.4. Computer-based collaborative concept mapping: The Intervention

As discussed in the preceding sections, many studies, however separately, have investigated the effectiveness of concept mapping (CM), collaborative concept mapping (CCM), and computer-based concept mapping (CBCM) in secondary science learning, but very few (virtually nil) have investigated the effectiveness of computer-based collaborative concept mapping (CCCM) on conceptual learning and motivation in the Indian secondary school science context. Moreover, no study until now has examined motivation toward science learning in the Indian context, even in a similar way as is proposed in this research project. As mentioned in chapter one, this study aims to investigate the effects of CCCM on motivating underachieving (M. Walker, 2011) and unmotivated Indian secondary students. Therefore, CCCM was designed keeping in mind the need to motivate Indian students to learn science so that, in future, they can occupy a respected place in the international rankings, such as PISA. An overview and the design of the CCCM intervention are presented in the following sections 2.6 and 2.7.

2.6. Overview of the Intervention

2.6.1. Purpose

In relation to this study, one of the principal aims of computer-based collaborative concept mapping (CCCM) is to enhance motivation towards science learning (motivation to learn science) at the secondary school level. In other words, an important purpose of CCCM is to develop a motivational support system to achieve the projected goals of improved science learning and achievement. Another specific purpose of CCCM is to improve knowledge of selected science topics, that is conceptual learning and science achievement. Other sub-goals include the development of different/specific motivational constructs, cognitive and meta-cognitive strategies, higher-order cognitive skills, collaborative, ICT, scientific thinking and communication skills of Indian secondary students. An additional goal is to use and evaluate the CCCM intervention as an innovative assessment strategy for formative and summative assessment, to make students' thinking visible and monitor their progress in science learning.

2.6.2. Materials

The most important tool in the CCCM intervention is the concept mapping software. In this research the latest version-9 of the *Inspiration* software (http://www.inspiration.com/visual-learning/concept-mapping) was used by the researcher, teachers and students to construct concept maps on different topics. Some concept mapping software, such as CMaps, MindMaple, and MindMup, are also freely available but Inspiration is more interactive, user-friendly and has some specific features, for instance, capacity to insert photos into the concept maps. Other important materials included some concept maps previously prepared by the researcher for teacher training and the lesson plans prepared in consultation with the participating teachers.

2.6.3. Classroom lessons

The duration of the CCCM intervention was ten weeks, in addition to the two weeks training and practice using paper-pencil concept maps. Daily science class periods of 50 minutes as assigned in the school time-table were used six days a week. Occasionally, in the beginning, the ICT periods and some free periods were also used to practice concept mapping. Most of the lesson plans were organised according to the structure agreed by the participating teachers and researcher. Two types of lessons were designed. In the first kind of lesson structure, the teacher had to present the overview of the concept for the first 10 minutes, which was followed by the group activity (discussion and concept map preparation) for 30 minutes, and the last 10 minutes was used to present the group work to whole class and to discuss this work. The second type of structure, required students to continue working on their concept maps for the first 25 minutes and the second half of the 25 minutes was used to organise whole class discussion about the concepts and concept maps. Special care was taken to minimise the disturbance to the on-going classwork. Once students got familiar with the concept mapping and software, only time for the science lessons in the school time-table was used for the intervention.

2.7. Design of the intervention

The CCCM intervention was designed keeping in mind the earlier reported low interest of, and the need to motivate, Indian secondary students. The underpinning theoretical perspectives, assumptions, strategies and components of the CCCM are described in the following sub-sections.

2.7.1. Theoretical framework

Social cognitive and sociocultural theories of learning and motivation are the guiding frameworks for the CCCM design, which have been discussed in earlier sections of this chapter. The instructional strategy based in social-cognitive and sociocultural theories used in the CCCM design is collaborative learning. To implement the collaborative learning approach, the basic features of the important and relevant strategies of *thinking together* (Dawes, Mercer, & Wegerif, 2000; Kuhn, 2015b; Mercer & Littleton, 2007; Wegerif, 2004) and *Interthinking* (Littleton & Mercer, 2013) which are at the heart of the intervention, were primarily adapted and implemented. The ground rules (see appendix A) were framed based on these strategies. In relation to the collaborative learning, specific empirically verified strategies such as *Exploratory Talk* (Edwards-Groves, Anstey, & Bull, 2014; Mercer, 2010; Mercer & Littleton, 2007), *Educational Dialogues* (R. Alexander, 2006, 2015; Littleton & Howe, 2010; Mercer et al., 2009; Mercer & Howe, 2012) and *Argumentation* (Crowell & Kuhn, 2012; Kuhn & Moore, 2015; Osborne et al., 2013) were adapted and used to structure the lessons and establish the 'ground rules' to work in groups. The motivational aspects of expectancy-value, goal orientations, use of active learning strategies and design of a motivational learning environment also guided the design of the instruction, providing a multiple component motivation intervention structure. In relation to the motivational components, an explicit emphasis was put on the development of self-efficacy, value of science learning, performance and learning goals and use of active learning strategies to understand science by the teachers and researcher.

2.7.2. Underpinnings

Consistent with the theoretical and available empirical literature, it is believed that the development of motivation to learn science can activate internal motivation, cognitive structures, and emotional states of students. In short, a motivated learner of science is interested in learning science, demonstrates favourable attitudes and understands science concepts to satisfy his/her curiosity. The motivated learner of science uses active learning strategies, such as concept mapping, to organise knowledge (connection, association and contrasts of prior knowledge with new knowledge), organise, manage and change (if needed) his/her knowledge structure, develop conceptions that are scientifically valid; and make sense of information. The motivated learner of science is also perceived as willing to expend effort, participate, show persistence in difficulties and display overall positive attitudes towards science learning. All these three components of intrinsic motivation, use of active learning strategies and emotional perseverance, are believed to be correlated and act together to promote the overall motivation towards science learning.

2.7.3. Instructional and motivational components

Based on the structural components of motivation to learn, for example cognitive, affective, intrinsic and extrinsic, and consistent with the operational definition of motivation to learn science offered in section 2.3.2, nine instructional tactics or components of the CCCM intervention were decided. These instructional components were framed primarily based on the relevant learning and motivation theories discussed in earlier sections. The instructional components derived from and associated with the motivational components are:

1. Goal orientation
2. Science learning value
3. Personal relevance
4. Internal motivation (interest, curiosity, cognitive needs such as self-efficacy, self-worth and self-determination)
5. Active learning strategies use (cognitive and meta-cognitive such as concept mapping)

6. Collaboration (trust, responsibility, support and common goal)

7. Social (inclusion, relatedness and interaction)

8. Emotional (persistence, emotion regulation and management)

9. Authentic assessment (to monitor the progress, formative, summative and self-evaluation)

Each of these instructional components consists of a motivational aspect and a cognitive element because the motivation to learn science cannot easily be promoted in isolation from cognitive functioning. For example, to develop interest and arouse curiosity, which is considered inherent in intrinsic motivation, students' prior knowledge, the nature of the content and self-related beliefs play important roles. The teacher needs to consider the key role played by each of these and needs to explicitly focus on and highlight these components in their instruction.

All of these nine instructional tactics have at least one associated motivational construct. The six constructs of motivation to learn science used in this study are:

1. Mastery and performance goals

2. Science learning value

3. Self-efficacy

4. Active learning strategies

5. Learning environment stimulation

6. Self-regulation

All these motivational components are believed to be interconnected and influence each other to promote higher or lower levels of motivation to learn science. The first five of these components are the same as listed by Tuan et al. (2005) but the sixth component of self-regulation was added to these five in order to design a more comprehensive intervention for motivating students to learn science. As discussed earlier, each of these six motivation components can affect science learning and achievement by affecting the previously outlined nine instructional components. Therefore, the CCCM intervention used for developing motivation towards science learning focussed on the nine instructional components listed earlier. It is important to note that each one of the instructional components can affect one or more motivational process and each of the instructional strategies play a key role in developing its related motivational component.

In addition to the emphasis on instructional and motivational components, the design of the intervention is also informed by *TLRP's ten principles for effective pedagogy* (see James & Pollard, 2011, 2012). These ten principles stress the primacy of dialogic pedagogy (educational dialogues, discussions, talks and argumentation) or dialogic teaching to improve students' learning as suggested by Alexander (2006). In relation to giving talk the central place in education, Alexander (2006) argues that "Dialogic teaching harnesses the power of talk to engage children, stimulate and extend their thinking, and advance their learning and understanding" (p. 98). The important role played by dialogic talk in meaning and sense making through communicating, sharing, interpreting and negotiating meanings is well described by Edwards-Groves et al. (2014) and, Mercer and Littleton (2007). Some researchers of science education such as Mercer and Littleton (2007), Littleton and Howe (2010), and Littleton and Mercer (2013) have described different forms of talk (for example, exploratory, collective, reciprocal and cumulative talk) and dialogic pedagogy in relation to their specific applications to science education. The inherent (sociocultural) thesis based on the research carried out by these researchers is that students learn and achieve more when they are involved in activities which along with providing opportunities for discussions, dialogues and arguments, also take care of the interaction, peer-support, relationships, trust, responsibility and accountability on the part of the collaborators (Wentzel et al., 2014; Wentzel & Brophy, 2014; Wentzel & Watkins, 2002).

2.8. Conceptual framework

A conceptual framework is an important part of a doctoral research project and provides a clear outline of the process of a study in terms of its proposed aims, constructs and concepts to be explored and variables under investigation (Berman & Smyth, 2015). In a study, it may be explicit in the form of a diagram which "specifies the variables of interest and the expected relationships between them" (Bickman & Rog, 2009, p. 7) or implicit in the form of operational definitions and variables. Berman and Smyth (2015) state that in a doctoral research, the explanation of a conceptual framework is “often implicit, however the role is more explicit” (p. 126). A conceptual framework can be considered as a knowledge organising and analysing tool that can present essential themes, features and processes of a research study. Green (2014) describes a conceptual framework as a map of a study that provides a rationale for the development of research questions and hypotheses and helps researchers in focussing “their minds on what the research is trying to achieve” (p. 35). It generally summaries the research aims, hypotheses, and operational definitions, essential and related concepts that could inform the whole research process.

Maxwell (2009) describes a conceptual framework as “a system of concepts, assumptions, expectations, beliefs and theories that supports and informs your research” (p. 222). This definition suggests that a conceptual framework, in addition to presenting important theoretical concepts, also outlines a researcher’s beliefs, assumptions and outcome expectations. Similarly, Punch and Oancea (2014) consider a conceptual framework as something that shows the conceptual status among the central concepts of a piece of research. Shields and Rangarajan (2013) define a conceptual framework as “the way ideas are organised to achieve a research project’s purpose” (p. 24). The authors describe the meaning and functioning of a conceptual framework using the metaphor of American football play. Shields and Rangarajan (2013) argue that like the football play has a plan of action which is tangled to a particular and timely purpose, the conceptual framework connects the research purposes, hypotheses, data gathering and analysis tools. Therefore, these authors suggest an idea of conceptual framework-research purpose *pairing* in order to help doctoral researchers in developing their research designs.

Although the terms theoretical and conceptual framework are often used interchangeably in the academic world, they refer to two different concepts. The former is derived from or based on an existing theory or theories (e.g. theory of motivation and learning) and has a more theoretical orientation. The latter, in contrast, is an organised and planned outline (generally in the form of a diagram) of some or all of the concepts, constructs and variables that the relevant theory/theories emphasize/function with, and has a more practical orientation. Green (2014) describes the confusion prevalent in the academic literature between the two terms and suggests that researchers should not get hung up on the terminology. Doctoral students can get easily confused because very little is written about the explicit difference between these frameworks and available literature does not provide much help (H. E. Green, 2014). Green (2014) argues that some research approaches such as *Grounded theory*, might not even appear using a conceptual or theoretical framework because of the nature of the approach in which the theory is generated on the basis of data gathered. The common conclusion that Green (2014), Berman and Smyth (2015) and other scholars provide is the usefulness of designing and drafting the conceptual framework in a study. Therefore, these researchers encourage emerging researchers especially doctoral students to design and refine their conceptual framework as the research process proceeds.

In line with the Maxwell's (2009) definition and Berman and Smyth's (2015) guidelines, the conceptual framework of this study was designed (displayed in figure 2.2 below) in terms of the key theoretical concepts, their perceived relationships, researcher's beliefs, assumptions and expected outcomes of the research.

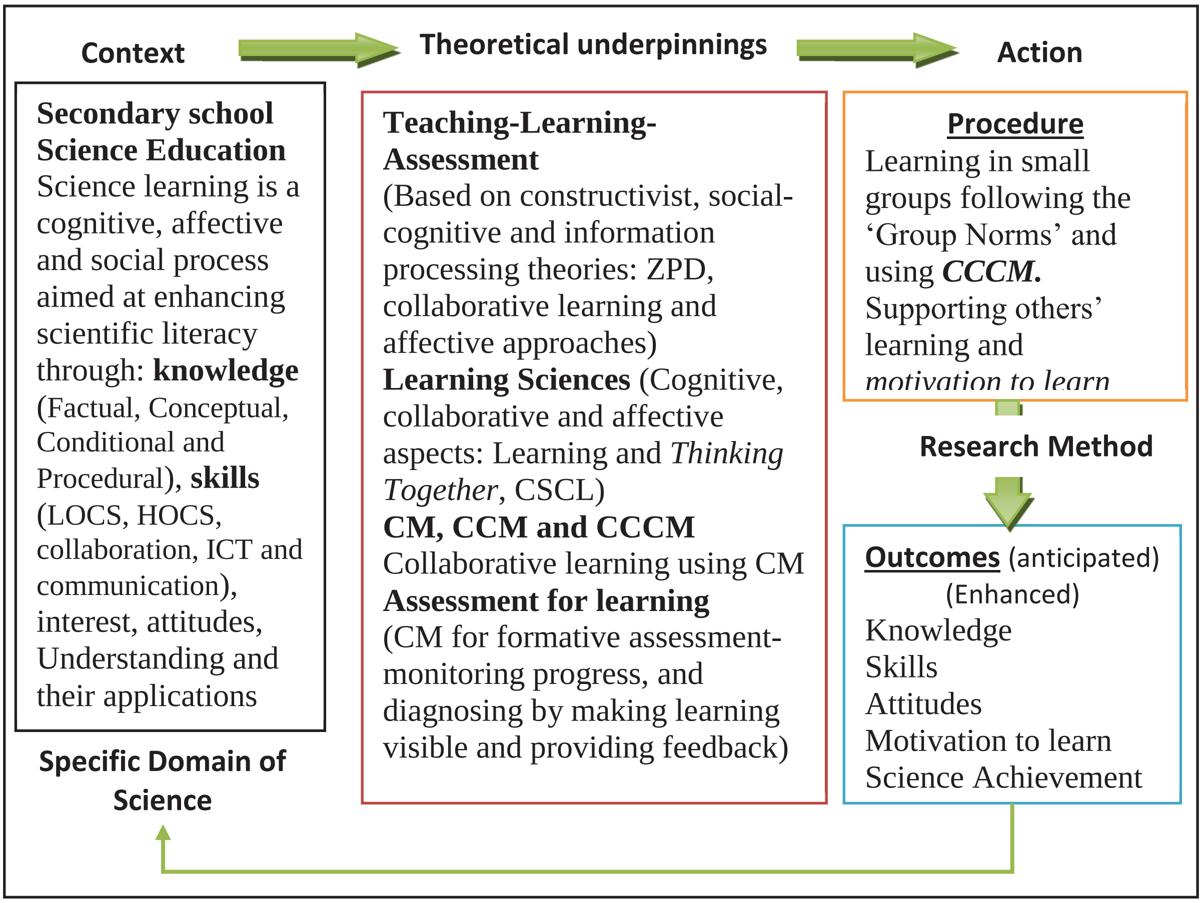


Figure 2.2 Conceptual framework of the study

The left hand side box in figure 2.2 describes the nature of secondary school science learning as a process of improving science learning as a result of enhanced knowledge, skills, interest and attitudes, understanding and applications of all of these to achieve the scientifically valid understanding of science concepts. This box, in other words, indicates the context of the research project. The middle box in the diagram shows the teaching-learning-assessment approach proposed as an integration of different theories and strategies of teaching and learning. This box outlines some of the strategies based on some recent theories and approaches which have been reported as worthwhile in the science learning and teaching literature. In other words, this box provides a theoretical description of the research. The small right hand side upper box in the diagram shows the intervention in terms of application of CCCM and its constituent/supplementary components. The lower box on the right hand side of the figure outlines the expected outcomes of the study as a result of intervention. Overall, the focus of the research on conceptual learning and motivation towards science learning is made explicit in the conceptual framework at every stage of the process. The procedures, plan of action and the expected outcomes address the research purpose as shown by the arrows in the diagram.

2.9. Research Questions

In relation to the motivation and motivation to learn science constructs discussed earlier and in relation to the objectives of current study (section 1.5), some general questions about the use of CCCM in secondary school science could be framed as: Why do secondary students choose to learn science? What levels of interest and engagement do they show and how much do they enjoy science learning? What strategies do students use and adopt to understand science? What value do students associate to science learning? What sort of goal orientations can be observed? How long do students sustain the science learning activity in the case of difficulties and how firm and confident are they to understand science concepts? However, only a few of these are explored in the current study. Specifically, this research was conducted to seek answers to the following research questions:

1. What is the effect of computer-based collaborative concept mapping (CCCM) on the achievement and conceptual learning of Indian secondary school students in science?

2. What is the effect of computer-based collaborative concept mapping (CCCM) on Indian secondary school students' motivation towards science learning?

3. How do Indian secondary school science teachers and students perceive and experience the use of CCCM in their classrooms?
4. What do Indian secondary school science teachers and students identify as enablers to and barriers in the CCCM use in Indian secondary school classrooms?

The first two research questions require both quantitative and qualitative data to answer. Therefore, the three hypotheses presented in the following section 2.10 are related with these two questions. The remaining two research questions are of qualitative in nature.

2.10.Hypotheses of the study

The major hypotheses of the study, in relation to Research Questions 1 and 2 are:

Hypothesis H_1: CCCM affects science achievement of Indian secondary students.

Null Hypothesis H_o1: CCCM does not affect science achievement of Indian secondary students.

Hypothesis H_2: CCCM affects conceptual learning of Indian secondary students in science.

Null Hypothesis H_o2: CCCM does not affect conceptual learning of Indian secondary students in science

Hypothesis H_3: CCCM affects motivation towards science learning of Indian secondary students.

Null Hypothesis H_o3: CCCM does not affect motivation towards science learning of Indian secondary students.

This chapter reviewed the literature related to learning, motivation and strategies for meaningful learning and motivation to learn science, leading to the research questions of the study listed at the end of the chapter. The following chapter presents the discussion about the research methodology and the procedures employed to carry out this study.

Chapter Three. Research Methodology

This chapter presents an overall description of the research methodology and research procedures. At the beginning, the nature of educational research and major research paradigms are discussed. The choice and use of pragmatism as the paradigm for the research is also described and justified. Design-based Research (DBR) as the suitable methodology for the study is explained and argued. Then the research design employed is described. This is followed by a description of the data generation tools and the research procedures. After that the procedures for analysing the data are discussed. Finally, the ethical issues related with the research are outlined and discussed. The results obtained from the data analyses are presented in chapter four.

3.1. Research in education

Educational research may be characterised as a systematic process of studying an educational phenomenon/issue which generally involves collection and analysis of data and is carried out with an intention of adding to the knowledge and to improving conditions (learning, schooling, development). Considering education as a social science, Clough and Nutbrown (2012) provide a comprehensive definition stating, "All social research sets out with specific *purposes* from a particular *position*, and aims to *persuade* readers of the significance of its claims. These claims are always broadly *political*" (p. 4; emphasis in original). In terms of the functions of research, this definition informs the reader about the four important aspects of social research printed in italics. Social research is a purposive inquiry which has specific purposes to fulfil such as: understanding of social issues and phenomena, as well as verification of theory and extension of knowledge. One of the main objectives of the researcher is to persuade the reader about the significance, claims, impact and difference the research will make to the body of knowledge. From a broad political point of view, any educational research should have potential to impact on policy, practice, professional development and can provide stimulus for further research (Clough & Nutbrown, 2012).

Social research is positional in the sense that it is carried out in a specific context and from the standpoint of the researcher. Because it is social and people are always involved, it cannot take place in isolation and thus the context affects any research from two points of views. First, the social contexts in terms of the physical, geographical, cultural or community environments and their interaction which "gives it (research) [sic] its real meaning" (Clough & Nutbrown, 2012, p. 10). Second, the positionality of the researcher, from where it is carried out, affects every decision to be taken at various stages of the research. These decisions about the ways a researcher conducts an enquiry, such as types of research questions, the methodology and tools to be used and ethical considerations, are all affected by the positionality of the researcher. This position of the researcher is predominately linked with the purpose and nature of research and the phenomenon under study. Therefore, every researcher, whether or not he/she makes their position explicit in the report, has to acknowledge it from the outset and has to design their research accordingly (Clough & Nutbrown, 2012). This positionality of the researcher, in the technical terminology of research affects the choice of 'paradigm' and is explained in the following section.

3.2. Research paradigm

A paradigm is a way of looking at something. It is a set of beliefs and thoughts that provide different meanings and interpretations of the same event. All research is carried out in the light of beliefs and understanding of the world of knowledge. A research paradigm is "composed of certain philosophical assumptions that guide and direct thinking and action" (Mertens, 2015, p. 7) related to the research. A research paradigm therefore, consists of philosophical views, a comprehensive belief system and a framework that provides direction to any research. Because different researchers have different beliefs and thoughts about life, the ways in which research is carried out differs. Punch and Oancea (2014) note that in the research process, paradigms address following three types of fundamental questions related to any research:

1. *The ontological question*: What is the form and nature of reality and, therefore, what is there that can be known about it?

2. *The epistemological question*: What is the relationship between the knower (or the researcher) and what can be known (the researched)?

3. *The methodological question*: How can the inquirer go about finding out what can be known? What methods can be used for studying reality? (p. 17; emphasis in original)

In this way, paradigms are linked with (and have implications for) the methods used and thus methods mostly derive from paradigms (Punch & Oancea, 2014).

The ontological questions ask about the nature of truth (conceived as well as to be searched) that the researcher is exploring through their research. The nature of knowledge and the influence of the interaction of researcher with the participants are the issues explored by epistemological questions. The methodological questions ask about the suitability of research approaches and methods used to achieve the desired knowledge. Hence, a researcher has to acknowledge all the above mentioned philosophical aspects of any paradigm as these affect major decisions related to the conduct of any research.

Crotty (2003) proposes four essential and interrelated elements (figure 3.1) of the research process and stresses that these should be identified, explained and justified in terms of decisions made with respect to each of them. Epistemology, according to Crotty (2003) is concerned with making decisions about the nature, appropriateness and legitimacy of the knowledge to be searched. Obviously, these decisions about epistemological stances from the positivist, interpretivist, constructivist and realist points of view differ because of the different ways the nature of knowledge perceived. Ontology, being the science or study of reality/being, focuses on the philosophical nature of reality. There exists a dispute about the nature of reality among social scientists. Some think that there is one objective reality (positivists) while others (Interpretivists) propose multi facets of subjective reality. In Crotty's framework of research elements, ontology sits at the same level as epistemology and both of these inform the theoretical perspective. Therefore, ontology and epistemology inform the theoretical perspective (approach). According to Crotty (2003) these theoretical perspectives guide the methodology and method choice of the researcher as presented in figure 3.1.

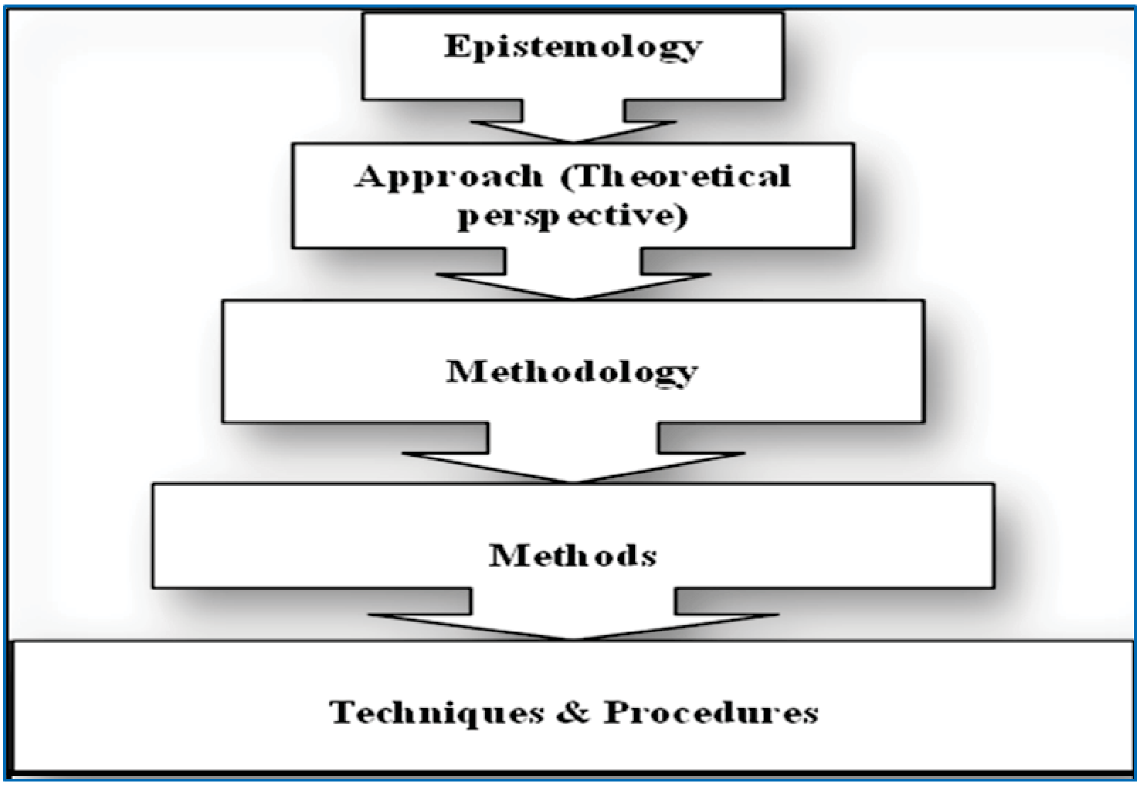


Figure 3.1 Crotty's theoretical grounding

3.2.1. Paradigm war and new paradigms

Historically, the two paradigms most commonly used in educational research were positivist and interpretivist (Guba & Lincoln, 2005). The philosophical foundations of the positivist paradigm are rationalism and empiricism. Positivists believe that there is 'a' method of studying the social world and it can be studied in the same way as the natural world. They believe that there is one objective reality which is value-free in the context. Positivists typically adopt a deductive or theory-testing approach and related methods such as random sampling, survey and questionnaires, to test hypotheses and theory. Interpretivists, in contrast, believe that multiple realities exist and these are constructed by the participants in the research. These subjective realities are values-based and are influenced by the context or environment. Interpretivists try to investigate how and why things happen according to the perspectives of participants and mostly implement theory-building approaches and related methods, for instance ethnography, in-depth interviews and case studies.

The contrasting beliefs of positivist and interpretivist 'purists' led to what Johnson and Christensen (2014) called the 'paradigms wars' which was at its peak in the research literature during 1980s. This ‘either-or’ position in favour of any of the quantitative or qualitative research approaches is called the *incompatibility thesis*. The main problem with the incompatibility thesis was an inability to recognise the complementary nature of mixing ideas, assumptions and methods, which was recognised by later researchers in the late 1980s (B. Johnson & Gray, 2010). These mixed method researchers proposed learning from the differences of views and the synthesising of good elements of both approaches (B. Johnson & Gray, 2010), rather than focussing on the differences in positions. Mayer (2000) argues that, “Scientific research can involve either quantitative or qualitative data; what characterizes research as scientific is the way that data are used to support arguments” (p. 39). Tunmer, Prochnow, and Chapman (2003) also recommend the “thoroughgoing integration” of qualitative and quantitative methods stating that it “is not only possible, but highly desirable” (p. 92).

The differing views about ‘worldviews’ or ‘mental models’ of many philosophers and educational researchers resulted in the emergence of some new paradigms such as constructivism, pragmatism, critical theory and many of their variations. Onwuegbuzie and Leech (2005) identified three paradigms (quantitative, qualitative, and pragmatist), Creswell and Plano Clark (2011) lists four (post-positivist, constructivist, participatory and pragmatist), whereas Teddlie and Tashakkori (2009) identifies five of the commonly used paradigms: . The main difference in the latter two classifications is the separation of positivist and post-positivist paradigms. More recently, educational researchers such as Mertens (2015), Hall (2013), and Mackenzie and Knipe (2006) have agreed on four major/dominant paradigms, namely post-positivism, constructivism, the transformative paradigm and pragmatism.

3.2.2. The research approach

Since the objectives and nature of research questions of any research are linked with the choice of methods and methodology to be used (Crotty, 2003; Morgan, 2014a; National Research Council, 2002), they also inform the design of the research. However, many researchers have suggested and explained an alignment of the philosophical aspects of ontology, epistemology, axiology and methodology to arrive at the choice of methods used and to situate the study in an appropriate paradigm. Therefore, keeping in mind the nature of the study (objectives/questions) and ‘guiding scientific research principle 3’ by National Research Council (2002) which reads, “Use methods that permit direct investigation of the question" (p. 62), the present research uses a mixed methods approach to investigate issues of conceptual learning and motivation. Morgan (2014a) prefers use of the term *integrating* over *mixing* to reflect the combined set of strengths/benefits of using both qualitative and quantitative methods. Another rationale behind using mixed methods is the integrated strength these methods can offer to fully understand and explore the phenomena of learning and motivation in classroom contexts. Moreover, the argument that Tunmer et al. (2003) provide asserting that the main aim of mixed method researchers should be to examine deeply and explicitly both qualitative and quantitate approaches and combine (integrate) them for research welfares, seems appropriate.

3.2.3. Pragmatism and mixed methods

Pragmatism as a paradigm has been mostly proposed and argued as providing philosophical and methodological foundations for the use of mixed methods research (Biesta, 2010; Creswell, 2010; Teddlie & Tashakkori, 2009). However, some researchers such as J. Green and Hall (2010), Mertens (2012) and Morgan (2014a) contend that the terms qualitative and quantitative point to types of data and not the philosophical dimensions of epistemology, ontology and design assumptions and thus suggest to avoid the use of mixed methods as paradigm, which many other researchers, such as (B. Johnson & Onwuegbuzie, 2004) and Creswell and Plano Clark (2011) had used in their writings. Mertens (2012, 2015) argues that paradigms themselves cannot be methodological in nature, rather these lead to the choice of methods based on the underpinning beliefs and careful reflection, whereas B. Johnson and Onwuegbuzie (2004) state that choice/use of mixed methods is a paradigm itself.

The word pragmatism etymologically comes from the Greek word 'pragma' (πρᾶγμα) which literally mean 'action' and consequence of an action. Pragmatism may be defined as "solving problems in a practical and sensible way rather than by having fixed ideas or theories" (Oxford Dictionaries Language Matters, 2016b). This definition points towards the non-theoretical and non-philosophical nature of pragmatism and suggests its practical nature. From a pragmatist point of view, knowledge comes from taking action and learning from the experiences and outcomes of these actions (Morgan, 2014a). All these meanings indicate the action-oriented nature of pragmatism rather than its philosophical nature as suggested by some researchers such as Mertens (2015).

Therefore, the major rationale behind using pragmatism as a guiding paradigm for the present study is its action-oriented nature because the focus of this research is designing, implementing and evaluating the teaching-learning intervention in response to the problems of learning and motivation encountered.

Morgan (2014a) states that pragmatism is "particularly appropriate" (p. 8) for mixed methods research and notes that there are a variety of ways these methods can be used. Johnson and Gray (2010) point to their bias towards 'dialectical pragmatism' as "a philosophical partner of MM (mixed methods)" (p. 72) and argue that multiple perspectives should be dialectically examined to "create workable solutions in addressing important research questions and social problems" (p. 72). In this way, Johnson and Gray (2010) propose pragmatism as an appropriate paradigm for the conduct of mixed methods studies. However, others such as Hall (2013), argue in favour of using the realist paradigm, pointing to the "serious limitations" (p. 1) associated with pragmatism and stating that "pragmatism does not enter in to the choice of mixed methods nor justify its use" (p. 4) for conducting mixed methods research. Others, for instance Taylor and Medina (2013), propose the use of multiple paradigms in the form of a "new *integral paradigm*" (p. 9) to design new and hybrid methodologies and epistemologies for mixed method research. This multiple paradigm stance is also supported by B. Johnson and Gray (2010), who advocate for *ontological pluralism* and label it as *multiple realism* which, they state, is a product of embracing all types of objective, subjective and intersubjective realities. Egbert and Sanden (2014) are also of the view that multiple paradigms can produce rich results for some research. Choice of pragmatism as an appropriate paradigm in relation to current research is discussed and argued in the following section.

3.2.4. Pragmatism as an appropriate paradigm

On one hand, positivism (and post-positivism) appears appropriate to this study because of the teaching experiment (intervention) and the quasi-experimental research design used to carry it out, while on the other hand, constructivism also seems appropriate as students studied science concepts in small groups using discussions, dialogues, and argumentation to construct knowledge in groups (see section 2.7). The thesis of one objective reality does not work in this case because elements of social the context (interactions, co-construction, cultural etc.) and emotions (beliefs, values) are involved in the process of knowledge construction in the classroom context. Therefore, positivism (and post-positivism) does not appear to be an appropriate paradigm to guide the enquiry. Constructivism allows for multiple subjective realities based on social interaction. But because scientific knowledge (related to scientific laws, theories and facts) is not subjective in nature as is the case of social science subjects, there is typically only one kind of ‘true’ (scientific) knowledge in science. Moreover, as knowledge construction depends on diversity in prior knowledge and beliefs, it can lead to misconceptions, wrong or alternative conceptions or different conceptions to those that are agreed upon by the scientific community. Therefore, this study also overlaps with constructivism to some extent.

The researcher instead has taken a pragmatist stance in this study. The overall belief about pragmatism use, in addition to its ‘whatever works’ approach, is that pragmatism stresses action and learning from experiences (reflection) which fits the focus of the current study. In addition, pragmatism also provides a suitable research framework in terms of the process of *enquiry* for the conduct of this study (methodology) as advocated by John Dewey (cited in Morgan, 2014b). This aspect is explained in the following section 3.3.

In relation to the use and justification of pragmatism as an appropriate paradigm for this research, it is important to consider its ontological, epistemological and methodological aspects. Pragmatist researchers adopt external but multiple views of reality (as opposed to positivist and realist) and choose the best one to answer the research question. For pragmatists, an ideology or reality is true if it works (practically) to solve problems in a particular context. This view of practical reality is also affected by the belief: what works for whom in specific context, which is not philosophical in nature but has practical value for the study (Morgan, 2014a). Morgan (2014b), however, calls it a ‘new paradigm’ which is philosophically more sound and has more practical implications than its previous versions in the nineteenth and early twentieth century (1860-1930). Pragmatists believe that there is such a thing as reality but it keeps changing with time based on our actions. Pragmatist researchers appreciate all of the objective, subjective and intersubjective realities and their interrelations (B. Johnson & Christensen, 2014; B. Johnson & Gray, 2010) to work out what is ‘best’ in a specific context. Pragmatists are therefore, interested in finding out what, why and how something works in specific contexts, for example, in the case of present research the CCCM intervention.

Epistemology, as a theory of knowledge, considers the legitimate nature of intended knowledge and the relationship (interaction) of the knower with the knowledge. Pragmatists believe that either observable phenomena or subjective meanings or both can provide legitimate and acceptable knowledge depending upon the research question or objective of the research (Morgan, 2014b). They therefore integrate different perspectives to generate and analyse valid data and thus focus on practical and applied research. The implication of this pragmatist epistemology for the present study is that objective (individual and scientific) knowledge as well as subjective (collective and non-scientific such as misconceptions) knowledge will be examined critically and evaluated based on set scientific criteria. The focus of the study is the development and enhancement of scientific and legitimate knowledge which is free from ambiguity and is in line with consensual scientific views acceptable by the scientific community.

Methodology is related to the choice of suitable and valid methods to achieve the legitimate knowledge. For pragmatists, the criterion to decide the appropriateness of a method is to evaluate it in terms of achieving its purpose (Maxcy, 2003). Pragmatists put more emphasis on the question: *Why* use a given method and not another (Morgan, 2014b)? This is in contrast to the usual question: *How* to conduct research? This is only one aspect of the broader *why* question. Usually, the choice of methods in pragmatism is linked to the research questions. Morgan (2014a) labels pragmatism as a "paradigm of choices" (p. 8) because there are many complex choices available to integrate the strengths of qualitative and quantitative methods based on the nature of the research. At the same time, Morgan (2014a) also warns about the 'over simplified' meaning of 'what works' and suggests that quality issues (such as knowledge validity) should be considered critically before deciding on the methods to be used. Creswell and Plano Clark (2007) also stress the need to justify the use of mixed methods to achieve the research purpose and produce valid knowledge.

> The intentional collection of both quantitative and qualitative data… The investigators know the reasons that both types of data are needed, and they state these reasons. Also, rigor is added when the authors report detailed quantitative and qualitative procedures and use mixed methods terms to describe their study. (pp. 163-164)

Pragmatist aspects of methodology have two important implications for this research which guide the overall process. First, in terms of method choice, this study has used mixed methods both as multi-methods and as integrated methods to investigate the phenomena of conceptual learning and motivation to achieve legitimate knowledge in line with the scientific consensual views. Second, the methodology used (see section 3.3) is very similar to the *inquiry* process as recommended by Dewey (cited in Mertens, 2015; Morgan, 2014a). For Dewey, the inquiry (research) is a cyclic process which starts with the action and leads to the outcome/consequence. The researcher then evaluates the workability of the action and establishes his/her 'warranted beliefs'. These warranted beliefs again guide the line of action and the process of reflection go on until a workable and valid solution is reached (Mertens, 2015; Morgan, 2014a). This cyclic, reflective and iterative process is very similar to the Design-based Research (DBR) methodology used in this research to investigate the issues of learning and motivation. DBR is explained in the following section.

3.3. Design-based Research methodology

This study used design-based research (DBR) methodology from the outset through to its final retrospective analysis[10]. DBR methodology is "an emerging paradigm for educational inquiry" (Sandoval & Bell, 2004, p. 5). DBR is especially designed as a suitable research methodology for studying learning in natural classroom contexts (McKenney & Reeves, 2012; Oh & Reeves, 2010). DBR methodology, as compared to other research methodologies, is more practical and relatively new (T. Anderson & Shattuck, 2012). This might be the reason that DBR usually does not appear in regular educational research texts such as Creswell and Plano Clark (2011), B. Johnson and Christensen (2014), Punch and Oancea (2014) or Mertens (2015), which lists different research approaches. However, a very recent book by Bikner-Ahsbahs, Knipping and Presmeg (2015), titled *Approaches to qualitative research in Mathematics Education: Examples of methodology and methods* has included two chapters providing discussion about DBR. DBR, as an important and useful methodology, also finds some space in handbooks such as *The Cambridge Handbook of the Learning Sciences* (Sawyer, 2014b) and encyclopaedias, for instance *Encyclopedia of Science Education* (Gunstone,

[10] Retrospective analysis is the final phase of DBR process. More details in section 3.7

2015). Additionally, there are complete volumes of handbooks such as *Handbook of Design Research Methods in Education* (Kelly, Lesh, & Baek, 2008) and *Handbook of Design in Educational Technology* (Luckin et al., 2013), which extensively discuss and promote the use of DBR as a valuable methodology in education to solve complex problems related to teaching-learning. Although, DBR use has expanded and interest in DBR has been growing since the start of 21st century (T. Anderson & Shattuck, 2012; McKenney & Reeves, 2012; van den Akker, Gravemeijer, McKenney, & Nieveen, 2006), it seems that design-based research still is in initial and *emerging* phase (Bakker & van Eerde, 2015; Plomp, 2013).

DBR has been frequently used in education research, especially K-12 contexts (T. Anderson & Shattuck, 2012) to improve learning and related constructs. Given that design-based research is conducted in natural learning settings (classrooms, online) unlike controlled experiments, DBR "studies tend to be methodologically creative" (McKenney & Reeves, 2012, p. 8) utilising a variety of methods. The provision of natural learning environments ensure high degrees of external validity and thus robust and reliable results (McKenney & Reeves, 2012).

The origin of DBR methodology can be traced back to the early 1990s in the works of Brown (1992) and Collins (2003). Brown and Collins introduced the idea of *design experiments* to study the nature, process and assessment of learning in real, rich, complex and constantly changing learning environments (Neuman & Dwyer, 2011). From time to time, researchers have used different terminology to refer to design-based research methodology, for example *design-based research* (T. Anderson & Shattuck, 2012; Barab & Squire, 2004; Design-Based Research Collective, 2003; Wang & Hannafin, 2005), *design research* (McKenney & Reeves, 2012; van den Akker et al., 2006), *design experiments* (Neuman & Dwyer, 2011), *development research* (Gay, Mills, & Airasian, 2009), and *design-based implementation research* (Fishman & Penuel, 2013). The *Design-Based Research Collective* (DBRC) (2003) claims that their group coined the term *design-based research* (DBR) instead of using the terms *design experiment, development research* or *design research,* "to avoid invoking mistaken identification with experimental design, study of designers and trial teaching methods" (p. 5). However, popular and frequently used terms in the educational literature are *design-based research* and *educational design research*. Throughout this thesis, the term DBR is used along with occasional use of the term ‘education design research’ to refer to the literature.

3.3.1. Meaning and definitions of design-based research

Design-based research (DBR) is “the systematic study of designing, developing, and evaluating educational programs, processes, and products” (van den Akker et al., 2006, p. i). DBR usually puts emphasis on both research *through* design (intervention) and research *on* design (McKenney & Reeves, 2012) and influences both theory and practice (Plomp, 2013).

A more recent, practical and educationally suitable definition by Plomp (2013) explains possible functions of design-based research:

> to design and develop an intervention (such as programs, teaching-learning strategies and materials, products and systems) as a solution to a complex educational problem as well as to advance our knowledge about the characteristics of these interventions and the processes to design and develop them, or alternatively to design and develop educational interventions (about, for example, learning processes, learning environments and the like) with the purpose to develop or validate theories. (p. 15)

The above two definitions have explained the meaning of DBR in terms of the functions of designing, developing, implementing, evaluating and analysing the educational interventions (learning products). These definitions also indicate that the main aim of DBR is to add to the knowledge in the area of design, research and practice and ultimately try to minimise the fundamental gap between research and practice (McKenney & Reeves, 2012). In addition to basic research functions (to describe, compare, evaluate, predict or explain) of traditional research approaches, Plomp (2013) notes an additional function of DBR “to design and develop: e.g., what are the characteristics of an effective teaching and learning strategy aimed at acquiring certain learning outcomes?” (p. 13). This inbuilt aim of design and development is generally not the aim of other traditional research approaches such as experimental and case study research. Hence, DBR has implications for theory as well as practice. For theory, DBR strives to construct new and refine old theories of learning and instruction. And for practice, DBR produces new and innovative design artefacts or products which impact the practice of learning and teaching. Therefore, the design and research aspects of DBR help in the development and evaluation of a learning intervention, as well as in the development of local theories related to teaching-learning in real-world settings.

In terms of a theoretically suitable and useful methodology (Gravemeijer & Cobb, 2013; McKenney & Reeves, 2012; Plomp, 2013), the following definitions present some aspects of DBR as an approach to the educational research process.

Anderson and Shattuck (2012) define design-based research as:

> a methodology designed by and for educators that seeks to increase the impact, transfer, and translation of education research into improved practice. In addition, it stresses the need for theory building and the development of design principles that guide, inform, and improve both practice and research in educational contexts. (p. 16)

Wang and Hannafin (2005) define DBR as:

> a systematic but flexible methodology aimed to improve educational practices through iterative analysis, design, development, and implementation, based on collaboration among researchers and practitioners in real-world settings, and leading to contextually sensitive design principles and theories. (p. 6)

Barab and Squire (2004) define DBR broadly as “a series of approaches, with the intent of producing new theories, artefacts, and practices that account for and potentially impact learning and teaching in naturalistic settings” (p. 2).

Finally, the *Design-Based Research Collective* (2003) goes one step further and adds to the above mentioned aspects claiming:

> … design-based research goes beyond merely designing and testing particular interventions. Interventions embody specific theoretical claims about teaching and learning, and reflect a commitment to understanding the relationships among theory, designed artefacts, and practice. At the same time, research on specific interventions can contribute to theories of learning and teaching. (p. 6)

In this way the group argue that design-based research methods can be thought of as a coherent methodology which bridges theoretical research with educational practice.

From the above-mentioned definitions of DBR, it is evident that DBR is an innovative and practical methodology to carry out research in complex and real life situations such as classrooms and online learning environments to solve educational problems. The main goal of design-based research is to develop and understand the teaching-learning processes in actual classroom environments and to minimize the gap between research and practice. The *Design-Based Research Collective* (2003) argues that DBR blends empirical educational research with the theory-based designs of learning environments and thus it is an important methodology to understand *how*, *when*, and *why* interventions work. Moreover, DBR ultimately strives to develop systems to enhance learning in specific and realistic educational contexts (Plomp, 2013).

3.3.2. Characteristics and process of design-based research

From the above-mentioned definitions it is evident that the DBR methodology is flexible and complex because its nature depends on the focus (aim) of the research and thus keeps changing. Given the complex nature of DBR, it is difficult to compile all of the (standard) characteristics of DBR. However based on some previous work, van den Akker et al. (2006) characterize DBR as:

- *Interventionist*: the research aims at designing an intervention in the real world;

- *Iterative*: the research incorporates a cyclic approach of design, evaluation and revision;

- *Process-oriented*: a black box model of input-output measurement is avoided, the focus is on understanding and improving interventions;

- *Utility-oriented*: the merit of a design is measured, in part, by its practicality for users in real contexts; and

- *Theory-oriented*: the design is (at least partly) based upon theoretical propositions, and field testing of the design contributes to theory building (p. 5; italics emphasis added).

The description offered by van den Akker et al. (2006) suggests that DBR is a systematic process of designing, developing, implementing evaluating and improving educational interventions. By nature, DBR aims to solve complex educational problems by offering research-based solutions (McKenney & Reeves, 2012; Plomp, 2013). Therefore, design-based research can be characterized as a systematic and flexible methodology to study the impacts of theory-based learning and teaching interventions, with inherent aims to understand, design and evaluate the processes of learning and teaching in real classroom environments.

Like all other educational research approaches, DBR also follows a systematic and well planned process for its execution in a particular context. It is cyclic in the sense that the design ↔ development ↔ enactment ↔ analysis ↔ reflection ↔ revision process (cycle) continues until the problem is solved. This cyclic process of DBR research is shown in figure 3.2.

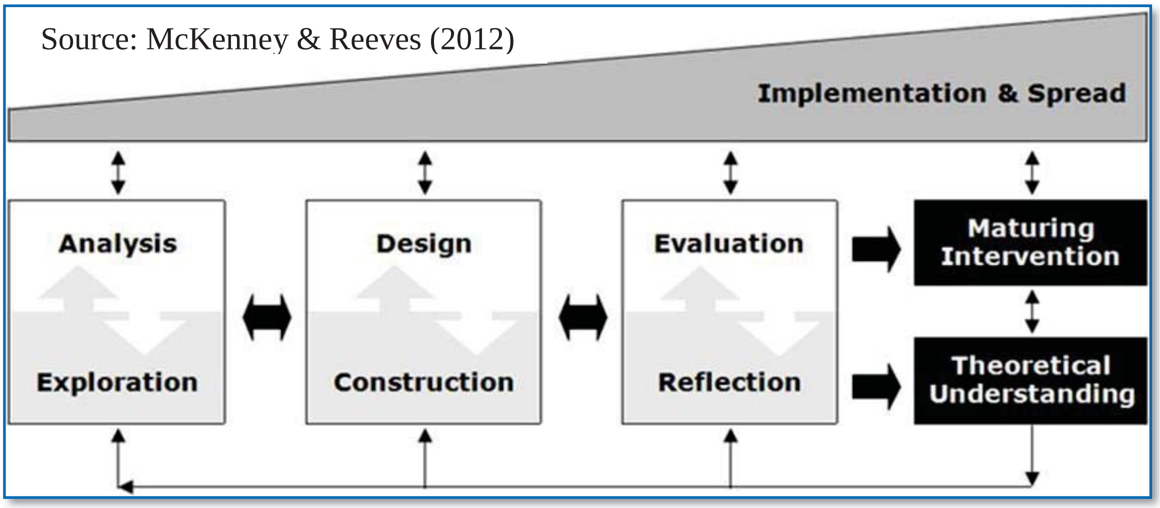


Figure 3.2 Generic model for conducting design-based research in education

The research cycle (process) starts with the analysis and exploration phase. The aim of this phase is to identify, diagnose, understand and define the problem in context. This phase usually involves a literature review, observations, meetings with experts and practitioners, field visits, preliminary interviews, etc. to generate rich data which help in understanding the problem thoroughly. The outputs from this phase inform the partial design requirements and thus help in generating initial design propositions based on the specific context (McKenney & Reeves, 2012).

In the design and construction phase, a tentative solution (usually in the form of a conceptual model of intervention) is proposed by designing a contextually suitable intervention. In addition, other potential solutions are generated, explored, considered, and mapped using different methods (McKenney & Reeves, 2012). At the final stage of this process, the design artefact is usually ready for implementation. The product is assembled and the design framework is articulated and justified.

During the evaluation and reflection phase, empirical testing of the intervention is done initially and then a detailed and thoughtful reflection is carried out to understand what, why and how the designed intervention worked (or not). This phase is similar to the first phase of analysis and exploration but involves more detail and rigour (McKenney & Reeves, 2012). The practical findings may suggest acceptance, refusal or revision based on the criteria of feasibility, validity, soundness, impact, effectiveness or broader institutionalisation of the intervention (McKenney & Reeves, 2012). An active and reflective analysis is done to establish valid solutions to the problem and to reflect on the practical and theoretical implications of the results. From the practical perspective, the results may indicate the conclusion or redesign/improvement of a particular intervention whereas, from the theoretical aspect, findings from this phase may add to the broader theoretical literature of related theories, frameworks and design of similar interventions. The two outputs of this phase mature with time and can be more locally applicable or more broadly relevant (McKenney & Reeves, 2012). Plomp (2013) describes these two outputs as, first the creation of "empirically underpinned innovative interventions" and second in terms of proposing the "design principles[11] or local theories" (p. 35). Therefore, this dual impact of DBR research on practice and theory is worth considering for the overall impact in the field.

As shown in the figure 3.2 the above-mentioned three phases interact with the implementation and spread aspect (shaded upper part) of the model. The shaded portion in the figure indicates the emphasis on the use of intervention which increases with time as the expertise of the researcher increases as a result of iterations and collaborations in the process. These three phases together make one complete cycle of the iteration process in any DBR study; a longitudinal DBR study needs many iterations to validate

[11] Design principle is the term used in the DBR literature to refer to resultant contextual, local and small domain specific theories to differentiate them with main theories in the field such as constructivism

the results (McKenney & Reeves, 2012). These iterations help the designer to review and refine the intervention if needed so that the intended and maximum impact is achieved. In masters and doctoral research much iteration is not possible because of the time and effort limitations and thus, the iteration is typically served by the first phase and the pilot of the research process. The practical aspects of the DBR research process (phases) for the current study are presented in section 3.7.

3.3.3. Design-based research as a suitable methodology

Design-based research is a relevant methodology for educational policy and practice research (Plomp, 2013) and suitable to study the effectiveness of learning interventions in real classroom contexts (Sandoval & Bell, 2004). Due to its applicability in technology-based learning environments its results are promising in relation to enhancing learning (Obrenović, 2011; Soong, 2010). This methodology is an intervention-based methodology. However, Soong (2010) argues that in addition to being intervention-based, DBR also takes care of two missing ingredients of the change process occurring in any DBR study. These two ingredients are the grounding of change in real classrooms contexts and active participation of teachers to transform the process of education through DBR. The present study was carried out to investigate the effectiveness of a computer-based learning intervention on conceptual understanding and motivation towards science learning in real classroom settings. The DBR research process involved the design, development, enactment (pilot, pre and post), evaluation, re-design and re-evaluation of CCCM to enhance the learning achievement and motivation towards science learning of Indian secondary school students.

The DBR process described in section 3.3.2 is similar to the process of inquiry as suggested by John Dewey (figure 3.3). Further, the iterative DBR research cycle is very similar to the action ↔ outcome ↔ reflection cycle which is the core of any pragmatist research (Morgan, 2014a, 2014b). From a pragmatist stance, human experiences are the core of the knowledge and these experiences always occur in a particular social context (Morgan, 2014a) and rarely occur in isolation. Dewey's general process of inquiry and the *Five-Step Model of Inquiry* (also called the *Doubly Reflective* model) are presented in figure 3.3 below and provide similar approaches (tools, methods) to solve practical, complex and contextual educational problems to that of a DBR approach. The five steps of inquiry, according to Dewey include encountering a problem, reflecting on the nature of the problem, identifying possible solutions, thinking about the effects of the possible solution and finally taking an action to solve the problem.

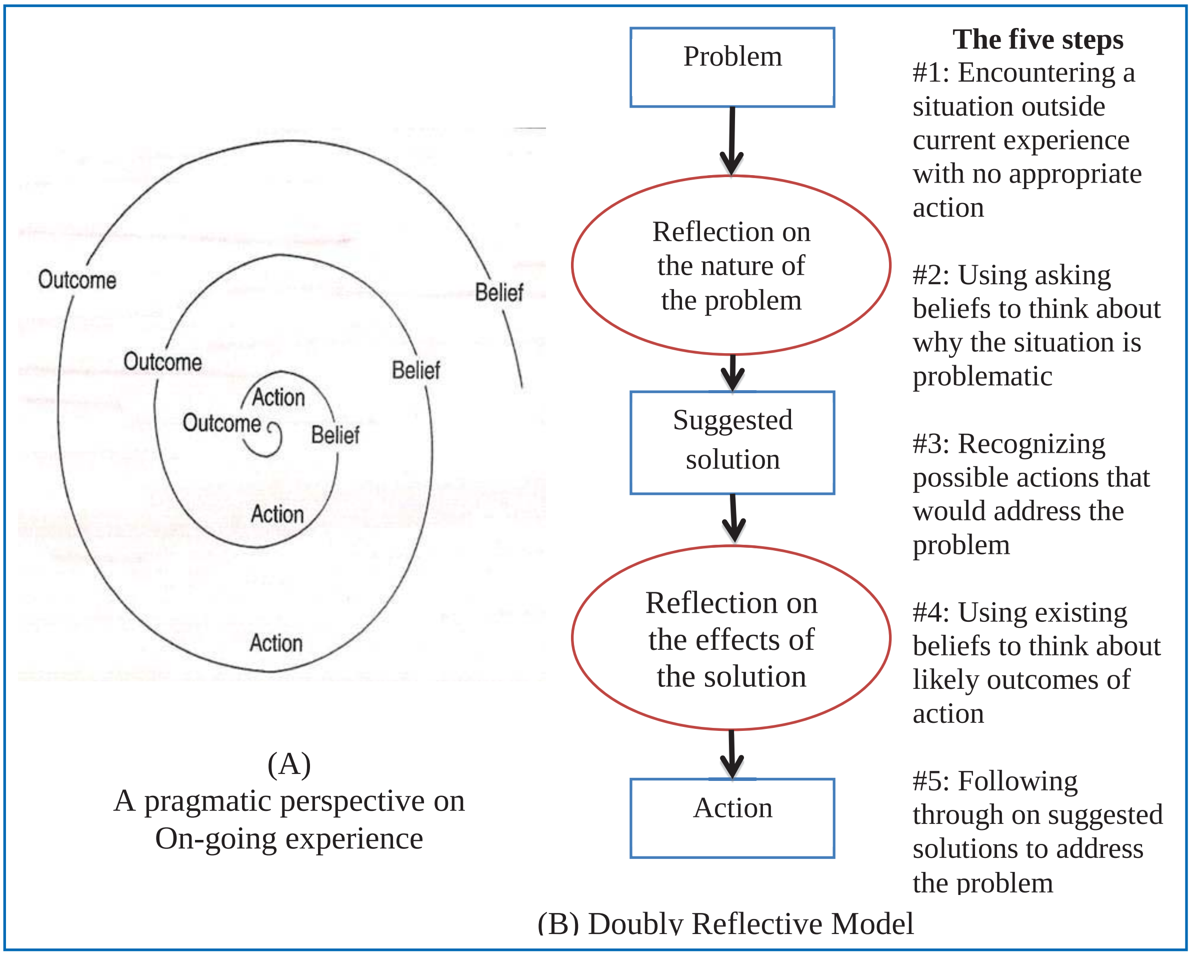


Figure 3.3 Dewey's Five-Step Model of Inquiry; adapted from Morgan (2014a)

Edelson (2002) presents three main reasons why educational researchers should engage in design-based research. The first reason Edelson outlines is due to its productive orientation to theory development because of its practical and goal-directed nature. The second reason is the utility of its results. The author claims that “education is a design endeavour” (p. 119) at its heart because in the process of education, at every level, almost each of the stakeholder, designs activities and products to improve the educational outcomes. Therefore, these design research products can directly respond to improve the system and existing practices. The third argument presented is due to the direct involvement of the researchers and almost all stakeholders in the process of education improvement. In this way design researchers can carry out and try truly innovative designs based on contemporary research on learning and teaching and can assess their effectiveness (Plomp, 2013). If successful, these designs can improve the teaching-learning process. In a nutshell, for the process of innovation and educational reform to happen, DBR appears to be an appropriate methodology to engage in.

Therefore, keeping in mind the research aims and nature of the current study, usefulness of the DBR methodology and some examples from the literature (e.g. Neuman & Dwyer, 2011; Soong, 2010), DBR is selected for the enactment of the present study. Moreover, use of the DBR methodology in real classroom environments can promote innovations (Design-Based Research Collective, 2003; Edelson, 2002) by offering innovative solutions and result in the development of local theories of learning (Jan, Chee, & Tan, 2010, June; McKenney & Reeves, 2012; Plomp, 2013).

The main goal of DBR is not to test educational theories (like in experimental research) but to develop and refine theories for specific contexts (Neuman & Dwyer, 2011) and to design and evaluate an intervention based on a theory. Barab and Squire (2004) also compare DBR with psychological experimentation and report that the main difference between them is that experimental research provides the proof for whether something works while DBR provides insight into how and why something works. Bakker and van Eerde (2015) provide some points of commonalities as well as differences between DBR and action research. The common characteristics they report are that both usually are interventionist, involve cyclic and reflective processes, and try to bridge the theory and practice gap. The major difference that Bakker and van Eerde (2015) outline is that in case of DBR the main focus is on instructional theory and design is a compulsory part of the research process. In contrast, in action research, the main focus is on action and improvement of the situation and design may be possible in the research. A researcher can be both a participant and an observer in DBR whereas in action research the researcher can only be a participant (T. Anderson & Shattuck, 2012). For more information on the differences between DBR and other methodologies the reader may refer to appendix O.

3.4. Research design

Given the practical, innovative and flexible nature of design-based research methodology, and its noted differences from other methodologies, DBR prominently fits with the pragmatist paradigm assumptions (Abdallah & Wegerif, 2014; Akilli, 2008). The pragmatic approach assumes that research problem and questions (objectives) guide the selection of methods (Punch & Oancea, 2014). Punch and Oancea (2014) note that a research study can proceed by adopting either a *paradigm-driven approach* or a *question-driven approach*. This study has adopted the latter approach and has utilised the flexible characteristic of DBR in terms of the integration of different research methods in a single study. The focus of the study was to investigate the effectiveness of the CCCM intervention in general and its impact on students' conceptual learning and motivation towards science learning in particular. Therefore, to examine the effect of CCCM on students' learning and motivation (the first two research questions, section 2.6), a quasi-experimental *Solomon four-group* research design was used to carry out the teaching experiment and to generate the quantitative and qualitative data for the study. These effects of the intervention were also examined by the qualitative data obtained from qualitative research tools (section 3.6) which generated the data for the other two research questions. Therefore, the intervention mixed methods design was used to carry out the current research. Creswell (2015) places the intervention mixed method design in the category of advanced mixed methods designs which is an additional category to the three basic designs: an exploratory sequential, the convergent and an explanatory sequential mixed methods research designs. Creswell (2015) also suggests researchers to work out the type of intervention mixed methods design based on set of procedures. These procedures involve determining how qualitative data will be used in the intervention trail in relation to any of the basic mixed methods designs, carrying out of the intervention, and determining how the qualitative data will be integrated with the quantitative results to support the findings. A generic mixed methods intervention design is shown in figure 3.4. Based on the diagram presented in figure 3.4, a diagram of procedures can be drawn depending upon the stage at which the qualitative data is being collected and used. The present study used the intervention mixed method research design which is an integration of the convergent and an explanatory mixed methods designs. For instance, qualitative data was collected during as well as after the intervention and was integrated to explain the outcomes of the experiment. Within the intervention mixed methods research approach, the Solomon 4-group research design served the main design to implement and evaluate the designed intervention.

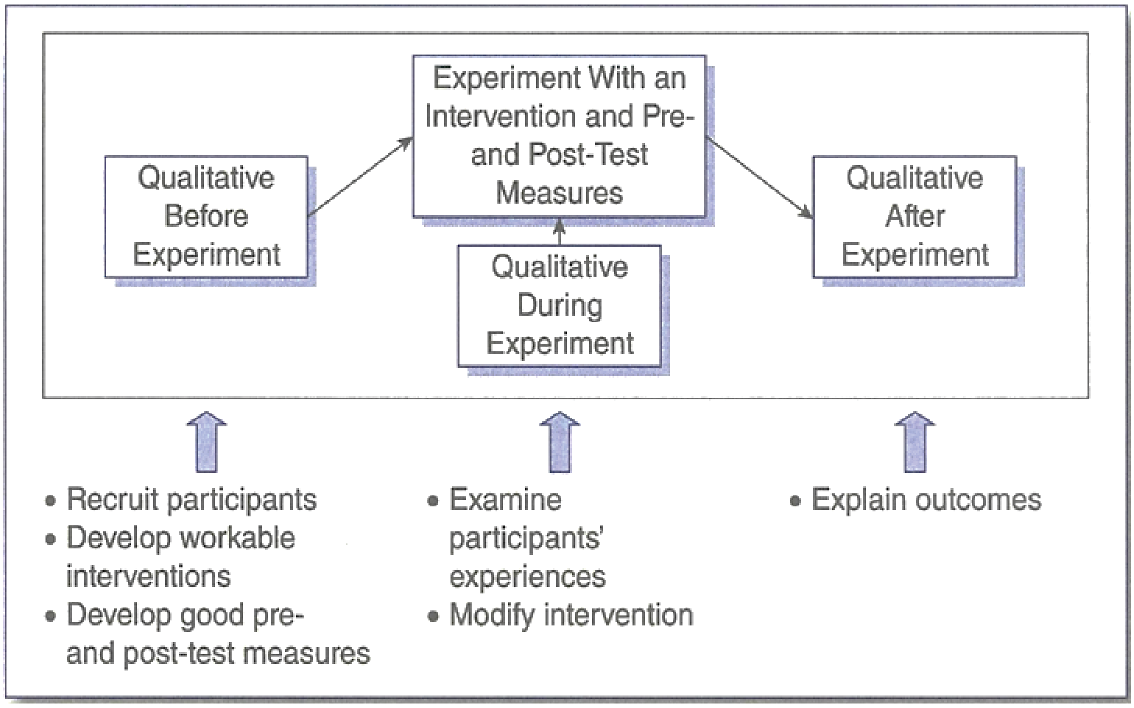


Figure 3.4 The generic intervention mixed methods design (source: Creswell (2015))

The *Solomon four-group* design is a combination of the pretest-posttest control group design and the posttest-only control group design (see figure 3.5; groups A and B forming the pretest-posttest while groups C and D form the posttest group only design). This integration of two designs in the *Solomon four-group* design "offers researchers the greatest amount of experimental control" (Martella, Nelson, Morgan, & Marchand-Martella, 2013, p. 144). This combination also ensures control over pretest-treatment interaction and mortality (Gay et al., 2009; Mertens, 2015) issues which may impact the validity of the results of a study. Shuttleworth (2009) states that the Solomon four-group design offers a robust check on most of the issues of internal validity and confounding variables by providing two extra control groups. For instance, the Solomon four-group design informs the internal validity issues related with history, maturation, testing, instrumentation, differential selection and mortality (Mertens, 2015). Mertens (2015) further comments that this design informs the external validity related to issues of novelty, pretest and posttest sensitisation and experimenter effects, and thus adds to the validity of results.

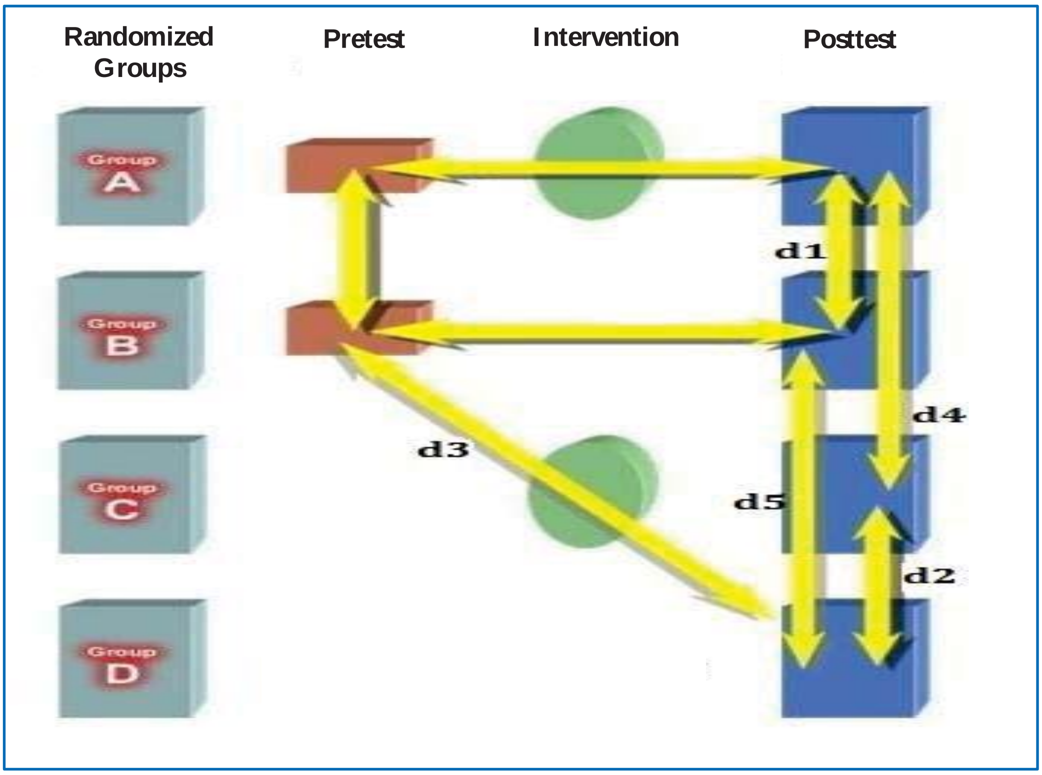


Figure 3.5 The Solomon four-group research design (adapted and modified; source: Shuttleworth (2009))

Following the Solomon four-group research design shown in figure 3.5, the researcher starts with selection of the participants and randomly allocates them to four groups to form the sample for the research. However, in this study, the participants could not be randomly assigned to the four groups because of the on-going curriculum in the classrooms at the time of study and keeping in mind the issues related to the school organisation and managements. Rather, they were adopted as the four intact groups (classrooms). Although, the two schools (figure 3.6) were randomly selected and the four classrooms were randomly assigned to the four groups, the current study is a quasi-experimental research design in nature.

As shown in figure 3.5, the two groups, that is group A and B were pretested and the other two (C and D) were not. The intervention (CCCM) was allocated to one of the pretested groups (group A) and to the one which was not pretested (group C). These two intervention group students studied science content using the CCCM intervention. The other two comparison group (groups B and D) studied science concepts using their ongoing traditional methods, mostly lecture method. At the end of the teaching experiment, all four groups of students were post-tested to examine students' conceptual learning and motivation towards science learning. The differences between the outcomes of the pre and posttests, indicated by d_1, d_2, d_3, d_4 and d_5 can provide the checks for pretest-intervention interaction, confounding and extraneous variables. For example, if the difference between d_1 and d_2 is significant, then pretests may have influenced the results; if the difference d_3 is significant then external factors may have influenced results (a check upon causality); if the difference d_4 is significant then pretests may have influenced the treatment; and if the difference d_5 is significant then the pretest may have influenced the results independent of the treatment.

The diagrammatic form of the quasi-experimental Solomon four-group research design of the current study is presented in the figure 3.6. This figure summarises the design to indicate the nomenclature of the schools, groups, pretest and posttest outcomes, and the intervention administered to the experimental and control groups in this study.

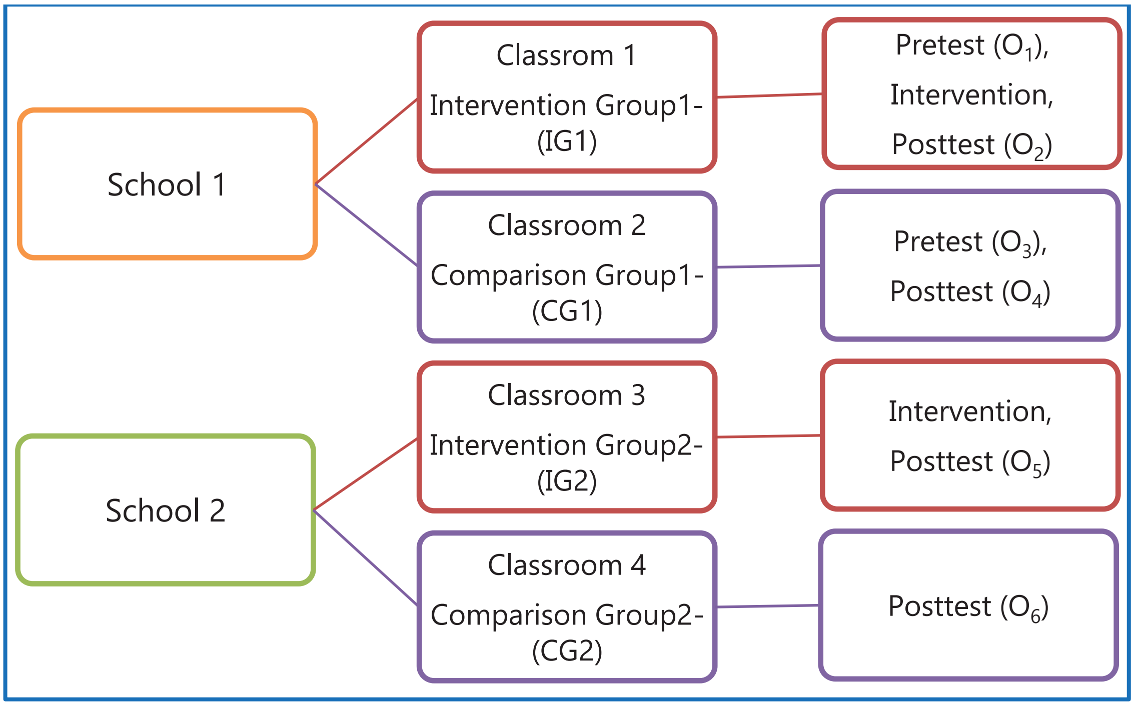


Figure 3.6 Quasi-experimental Solomon four-group research design of the study

Figure 3.6 shows that from school 1, the two classrooms 1 and 2 (equivalent to group A and B in figure 3.5), which form intervention group 1 and comparison group 1, were both pretested and post tested. From school 2, classrooms 3 and 4 (groups C and D), which serve as intervention group 2 and comparison group 2 were only post-tested. The intervention was administered to classroom 1 (group A) from school 1 and classroom 3 (group C) from school 2. The outcomes of the pretests are indicated by O_1 & O_3 and that of posttests are shown by O_2, O_4, O_5, and O_6 for classrooms 1, 2, 3 and 4 (groups A, B, C and D in figure 3.4) respectively. Other details of the Solomon four-group research design are presented in section 3.8.

3.5. Participants and sampling

The target population for this study included all the science teachers teaching 9th class (grade 9) and all students studying in 9th class in all the 91 government high and senior secondary schools in Chandigarh (India). The city was chosen because of its location and similarity of the sociological and educational contexts with the 7 neighbouring north Indian states: Punjab, Haryana, Himachal Pradesh, Uttaranchal, Uttar Pradesh, Rajasthan and National Capital Territory of Delhi. Chandigarh is a union territory (U.T., see section 1.2 of chapter 1) and a capital city of two states (provinces) of Punjab and Haryana and shares a boundary with three states of north India. This city was also selected keeping in mind the infrastructural facilities and generalizability of the results at least in the northern part of India.

Andres (2012) states that “the best sampling strategy for a given survey project is the one that is best suited to the study” (p. 96). Keeping in mind this suitability (intention and accessibility) and the purpose of the study, multi-stage cluster sampling was employed to select the sample of students and teachers. The sampling stages involved probability (random) as well as non-probability (purposive, convenience) techniques. The two secondary schools were randomly selected from the 73 government schools using lottery method to serve as two research sites. These 73 schools were selected from a total of 91 schools after dropping the 18 low achieving and high achieving schools. A total of 241 students from the two selected schools and the two science teachers (one each from each school) served the actual sample of the study. From school 1, a total of 112 students (57 from classroom 1 and 55 from classroom 2) and from school 2, a total of 129 students (67 from classroom 1 and 62 from classroom 2) agreed and participated in the research. From these two schools, four secondary science classrooms out of the existing six classrooms were purposefully selected to make the four equivalent groups in terms of science achievement. These four groups were randomly assigned to the two intervention and two comparison groups. The two science teachers, teaching the 9th class students were also purposefully selected keeping in mind the similarities in teaching experiences and their willingness to apply the intervention in their classrooms. The two teacher participants had completed their professional qualifications (Bachelor of Education) within a difference of two years. Both the teachers had also completed their master level qualifications: one in Chemistry and the other in Mathematics). According to the Solomon four-group research design, the four classrooms ideally should have been selected from the same population (one school) and should have been taught by one teacher. This was not possible because of diversity in medium of instruction (English, Hindi and Punjabi), unequal achievement levels among the students in classrooms within a single school and unavailability of four classrooms in most of the schools. Therefore, the four equivalent classrooms were purposively selected from the two schools and this purposive selection of the classrooms and teachers transformed the design to quasi-experimental.

3.6. Data gathering instruments

An implication of the truism that the efficiency of any skilled worker depends upon the efficiency and suitability of the tools might suggest that in the case of research, the effectiveness of a study largely depends on the suitability of the research tools. This study utilised a range of data gathering tools to generate the required and appropriate data. The study used achievement tests (pre and post), students' work samples (concept maps and response sheets), motivation questionnaire, semi-structured interviews and student focus group discussions. Details of each of the data gathering tools used are presented in the following sub-sections.

3.6.1. Achievement test in science

Achievement tests are generally used to measure the learning achievement levels of students. They can be constructed by the teacher or the researcher or through collaboration. The main objective of these achievement tests is to serve the specific research needs of researchers. However, these tests are rarely of high quality as compared to large international tests such as PISA and TIMSS (Hambleton, 2014). In some situations, achievement tests measure more than cognitive achievement. Achievement tests can also take the form of performance tests, which require students to perform (to construct a diagram, map, writing responses) some skills (Hambleton, 2014). Furthermore, these tests can either be norm-referenced or criterion-referenced in nature.

A norm-referenced test assesses a construct such as learning according to set scoring norms and usually compares students, whereas a criterion-referenced test assesses each student in terms of fulfilment of pre-defined criteria (Cohen, Manion, & Morrison, 2007). Hambleton (2014) comments that criterion-referenced tests are suitable for a study where the researcher is interested in assessing the levels of accomplishment of participants, as is the case of the current study, which was to determine advanced, proficient, intermediate and novice levels of achievement. These tests provide the researcher with rich evidence “about exactly what a student has learned” (Cohen et al., 2007, p. 416) and can indicate whether or not a given student achieved the set criteria. Such tests can be used to monitor learning progress and assess gains over a period of time, and may thus serve as formative assessment tools, for instance, serving the learning purpose.

Given the focus on assessment of students’ conceptual learning, the criterion-referenced *Achievement Test in Science for grade 9* (ATS9; appendix H) used in the current study was designed and developed to assess students’ science proficiency levels. Because part of Research Question One required assessment of students’ accomplishment in terms of achievement scores, the ATS9 also served the purpose of a norm-referenced test to compare students’ achievement across different classrooms. However, the overall objective behind the construction of ATS9 was to measure learning proficiency levels and analyse them with reference to other research tools.

The ATS9 was constructed based on the learning objectives and content (concepts) outlines of the five chapters from the science textbook (see notes for table 3.1), which were covered during the 10 weeks of the teaching experiment. The revised version of Bloom’s taxonomy (Krathwohl, 2002) was followed while designing the ATS9 items. The first three out of the four dimensions of knowledge, viz. factual, conceptual, procedural and metacognitive knowledge (figure 3.7) as suggested by Krathwohl (2002), were used to design the test items. The fourth aspect of meta-cognitive knowledge was dropped because the focus of research was on cognitive dimensions/skills only. An explicit focus on the development and measurement of the lower-order cognitive skills (LOCS) and the higher-order cognitive skills (HOCS) (Bramwell-Lalor & Rainford, 2013) was made explicit for the purpose of teaching, learning and assessment (see figure 3.7). The data obtained from the posttest scores of ATS9, is used to answer the first part of research question one (section 2.9) and the results obtained for the conceptual learning were used to answer the second part of research question one of this study.

The ATS9 (see appendix H) contains a total of 35 items, of which 12 are multiple choice items and the remaining 23 items require students to write open ended responses. Out of these 23 open ended questions 13 items are identified as LOCS and 10 items as HOCS. The LOCS items were classified in terms of three categories: *Proficient, Intermediate and Novice*, while the HOCS items were categorized in the four categories: *Advanced*, *Proficient*, *Intermediate* and *Novice*. Figure 3.6 shows the focused area of knowledge and cognitive dimensions of the ATS9 in relation to the development and assessment of LOCS and HOCS of students. Details of how each assessment item is delegated to the knowledge dimensions in ATS9 are presented in tables 3.1 and 3.2.

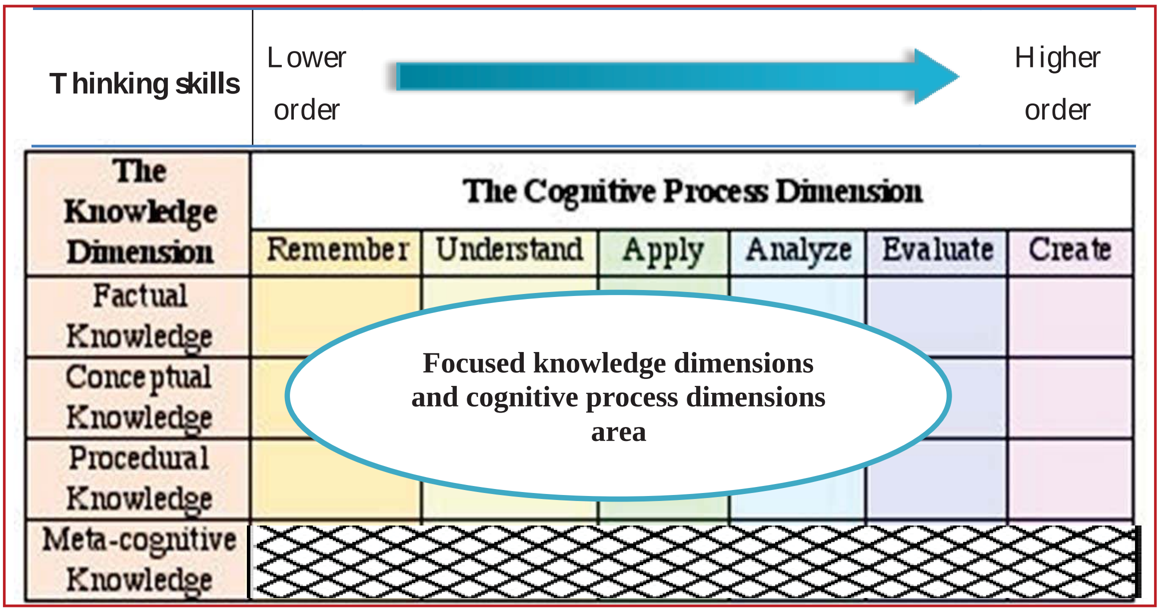


Figure 3.7 Focus of the Achievement test based on the revised Bloom's Taxonomy (adapted from Krathwohl, 2002)

The ATS9 was pilot tested with grade 9 as well as grade 10 students to establish validity and scoring reliability based on the set criteria for scoring. Face validity of the ATS9 was ensured by conducting group discussion involving the participant students and teachers during pilot testing. The feedback provided by students and teachers helped the researcher in refining some of the items. Content validity was maximized by discussing ATS9 items with two science teachers and two teacher-educators who generally design achievement tests for different examination boards. Most of the ATS9 items were compared to some of the achievement tests previously used by one of the examination board. To ensure reliability of the results, the ATS9 was applied to grade 10 students from two different schools along with a group of grade 9 students. Different responses obtained for the ATS9 items were compiled to ensure scoring reliability. The ATS9 assessment rubric (appendix I) and scoring criteria was established by the participant science teachers in collaboration with the researcher. Achievement scores were allocated to different ATS9 responses according to the defined categories of levels of conceptual learning.

Table 3-1 *ATS9 Blue Print: Chapter wise distribution of items according to cognitive process dimensions (adapted from Krathwohl (2002))*

Chapter*	Remember	Understand	Apply	Analyse	Evaluate	Create	Total**
3 and 4 (chemistry)	4#	21, 22, 25	2, 23	1, 3, 11, 12, 13, 14, 24			13(18)
7 (life sciences)	16	27,28		5, 6, 15, 26			7(10)
9 and 11 (physics)	8	17, 18, 19, 20, 31, 32, 35		7, 9, 10, 33, 34	29, 30		15(22)
Total	3(3)	12(20)	2(3)	16(20)	2(4)		35(50)

Notes: * Chapter3: Structure of the Atom, Chapter 4: Atoms and Molecules, Chapter 5: Diversity in organism, Chapter 9: Work, power and energy, and Chapter 11: Sound.
** Total possible achievement scores are shown in brackets with number of items for different chapters and cognitive process dimensions in the last column and last row: number of items (total score)
# indicates respective question number in the ATS9

Table 3.1 presents the distribution of items of the ATS9 according to the cognitive process dimensions and the chapters covered from the grade 9 science curriculum during the intervention period. The last column of the table shows the total number of items from different chapters and their corresponding achievement scores in parentheses. For example, from the two chemistry chapters a total of 13 items were designed which make up of a total of 18 marks (shown in brackets), out of the total 50 marks for the achievement test. Similarly, the last row of Table 3.1 presents the total number of items and maximum marks allotted each cognitive process domain.

Likewise, Table 3.2 presents the distribution of items and their respective scores in parentheses allocated according to the knowledge dimensions of factual, conceptual and procedural knowledge. The last column of the table shows the total items that assess a particular kind of knowledge and the total possible score a participant could achieve. The last row of the table shows the total number of items and their corresponding scores according to the six cognitive processes of Krathwohl's (2002) revised Blooms taxonomy of instructional objectives.

Table 3-2 *Taxonomy table for ATS9: Knowledge and cognitive process dimensions (adapted from Krathwohl (2002))*

The Knowledge Dimension	Remember	Understand	Apply	Analyse	Evaluate	Create	Total
Factual Knowledge	8#			5, 6, 9			4(5)*
Conceptual Knowledge	4, 16	17, 18, 19, 20, 21, 25, 27, 28, 31, 32, 35		1, 3, 10, 11, 15, 24, 26			20(28)
Procedural Knowledge		22	2, 23	7, 12, 13, 14, 33, 34	29, 30		11(17)
Total	3(3)	12(20)	2(3)	16(20)	2(4)		35(50)

Note: # indicates respective question number in the ATS9
* Total number of items and their respective possible total scores

The ATS9 (also served as a performance test) provided samples of students' work which were analysed for conceptual learning and compared with students' group concept maps (the following sub-section). Students' individual proficiency levels were evaluated against the group concept maps to assess their individual as well as group conceptual learning/understanding. Anderson and Krathwohl's (2001) revised Bloom's taxonomy: *A taxonomy for learning, teaching, and assessing*, was used to design the ATS9 items (Tables 3.1 and 3.2) as well as to guide the assessment process.

3.6.2. Concept maps

Concept maps (see section 2.5.1) were constructed by students in small groups on different science topics (concepts) out of the five units. Students used version 9 of *Inspiration* software (available from www.inspiration.com) to prepare concept maps on computers during their group discussions. The *Inspiration* software is very user-friendly and has the additional advantage of inserting photos, figures and different media from web pages or files, which might add to a concept map structure and effectiveness. *Inspiration* was found to be more effective than most of the concept mapping softwares such as *Cmap Tools*, *Freemind*, *MindManager* and *LucidChart*. The samples of some of the concept maps constructed by students are presented in chapter 4 (section 4.2.3). The main aims of the concept map construction using the intervention CCCM were to examine students' group learning, compare it with their individual learning and to investigate associations between them. These concept maps prepared by students in small groups provided important information about many aspects of learning by visualising students' learning on the maps. The groups were formed by the science teachers to ensure that mixed ability students are included in all the groups. Concept mapping also helped to monitor students' learning and thinking progresses while constructing the concept maps.

3.6.3. The Student motivation toward science learning questionnaire

The standardised *Students' Motivation toward Science Learning* (SMTSL) questionnaire (appendix J) developed by Tuan, Chin and Shieh (2005) was used to assess students' motivation towards science learning before and after the teaching experiment (pretest and posttest). The SMTSL questionnaire was designed to measure Taiwanese secondary school students' motivation towards science learning. The SMTSL questionnaire consists of 35 statements divided into the six scales of self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation. The statements on the SMTSL require the subject to respond on a 5 point Likert scale ranging from strongly disagree (1) to strongly agree (5). The items include positive and negative statements to cross-check and measure the bias in the responses.

Tuan et al. (2005) report the internal consistency co-efficient (Cronbach alpha) of the questionnaire equals 0.89, which is a good indicator of internal consistency and reliability among its six scales. This score indicates that the SMTSL questionnaire produces, similar results under consistent conditions. In other words, all the items of the SMTSL questionnaire are correlated and measure the same latent variable of motivation. The findings of the SMTSL questionnaire have also shown significant correlations with science learning attitude (r = 0.41) and science achievement (r = 0.40) scores and also have demonstrated its reliability and validity (Tuan et al., 2005). Before using the questionnaire in this study, permission from the authors (appendix K) was obtained.

The entire SMTSL questionnaire can be used to measure the total intrinsic motivation of a participant. A comparison can be made among participants' total mean scores from the questionnaire to compare two or more groups. Another comparison can be made between participants' scores for the above-mentioned six scales to calculate the scale-wise difference between groups. The minimum, maximum and mean scores for the entire questionnaire and its six components for high motivation, moderate motivation and low motivation, as suggested by Tuan et al. (2005), are presented in Table 3.3.

The first column of Table 3.3 shows the names of the six scales of the SMTSL questionnaire. The second column indicates the number of items in the corresponding scale. The third and fourth columns show the minimum and maximum possible scores of the scales. For example, if a participant responds *strongly disagree* to all the seven statements on the self-efficacy scale, the total score of that participant for self-efficacy will be 7. In the same way, if all seven responses given on the self-efficacy scale are *strongly agree*, the total score for the participant will be 35. The next three columns of the table show the standardised mean scores for low, moderate and high motivation as suggested by Tuan et al. (2005) based on their research. The last row of the table shows the corresponding values for the entire SMTSL questionnaire. This questionnaire was also administered as a pre and post-test.

Table 3-3 *Description of SMTSL questionnaire items and scales with respect to the possible low, moderate and high motivation scores (adapted and elaborated from Tuan et al. (2005)*

SMTSL Scale	Number of items	Minimum possible score	Maximum possible score	Mean Low motivation score	Mean Moderate motivation	Mean High motivation score
Self-efficacy	7	7	35	21.20	23.05	25.93
Active learning strategies	8	8	40	26.28	28.83	31.30
Science learning value	5	5	25	17.59	18.28	19.76
Performance goals	4	4	20	13.11	15.02	14.94
Achievement goals	5	5	25	13.37	18.00	18.82
Learning environment stimulation	6	6	30	19.41	20.12	31.31
SMTSL (entire)	35	35	175	113.96	123.30	132.16

3.6.4. Semi-structured interviews

One of the main purposes of conducting a research interview is to understand a social phenomenon by obtaining the type of information which a researcher cannot obtain by using purely quantitative methods such as achievement tests and questionnaires. A researcher chooses the suitable type of interview out of the structured, unstructured and semi-structured choices according to the research objectives and the depth and breadth of the information required to answer the research questions (Gill, Stewart, Treasure, & Chadwick, 2008). With the purpose of examining teachers' perceptions and experiences of CCCM use (section 2.9; research question 3) in their classrooms, face-to-face semi-structured interviews (appendix M) were conducted with the two science teachers involved in the study. Informed consent was obtained from the participant teachers.

A semi-structured interview generally contains a list of key questions to be explored to investigate an idea or aspect in detail (Gill et al., 2008). Cohen et al. (2007) refer to semi-structured interviews as using an 'interview guide approach', in which issues and aspects to be explored are planned and outlined beforehand, and sequenced during the interview. The major strength of this type of interview is that the interview process tends to be mostly systematic and produces comprehensive information (Cohen et al., 2007). However, semi-structured interviews are flexible in nature and sometimes yield critical information which a participant considers important but might not exist in the plan of the researcher (Gill et al., 2008). Therefore, keeping in mind the objectives of this research, the noted strengths of semi-structured interviews, and attainment of unpredictable important information, the semi-structure format of interview was employed. The interview format used in this study is attached in appendix M. The interviews were audio-recorded using two different recorders to put a check on the voice quality. In addition to exploring teachers' perceptions and experiences, these semi-structured interviews were also used to identify the enablers for and barriers perceived to (section 2.9; research question 4) the use of CCCM intervention in Indian secondary science classrooms.

3.6.5. Focus group discussion

The interviews conducted with a group of participants with an intention to study a social or psychological phenomenon are usually referred to as focus group interviews or focus group discussions (FGD). These focus interviews are important tools to gather data on group norms and norm-related issues (Short, 2006) such as group processes, consensus, conformity and dispute in the group. According to Cohen et al. (2007) the use of FGDs is especially useful when the members of the group have been working together for some time to achieve some common goal. The FGDs can produce comprehensive information building upon the collective thinking (Gibbs, 2014), experiences and a range of different perspectives from the members of the group. This type of rich information is not possible to obtain in the case of single subject interviews. Krueger (2009) states that because of the achievement of diverse information, in recent times, the focus group interviews have gained a special status and place in applied research fields such as social, behavioural, clinical, health care and marketing research.

Halcomb, Gholizadeh, DiGiacomo, Phillips, and Davidson (2007) outline the pros and cons related to the use and conduct of FGDs. The benefits or strengths, Halcomb et al. (2007) identify, consist of the achievement of different opinions, beliefs and values in a 'collective context'; assimilation of a range of ideas and concepts; cultural and linguistic suitability; listening to diverse perspectives; access to possibly large number of participants; learning from collective experiences; and production of good quality data. The challenges that Halcomb et al. (2007) outline include the expertise of the researcher to conduct a FGD and to analyse the complex data obtained; problems of confidentiality of the data because of the group situation; potential for conflict; lack of management and moderation of group interactions; production of poor data in some situations; production of complex verbal and non-verbal responses; and extra time involved due to track changes in the group discussions. The benefits of conducting a FGD, however, generally outweigh the downsides (Gibbs, 2014).

Keeping in mind the nature of information sought (collective voices, beliefs and experiences) and benefits of conducting the focus group, two FGDs of students were conducted. One group each from the two intervention classrooms participated in these FGDs. Each group consisted of five students. Students discussed the usefulness, applicability and appropriateness of the intervention for conceptual learning and motivation to learn science. The focus group discussions were organised with the help of class teachers and the researcher as moderator. The group discussion employed the semi-structured format similar to the individual teacher interviews following a pre-planned list of the issues (see appendix N) to be explored. The focus group discussions were both audiotaped and videotaped to get precise data and to avoid confusion due to many speakers.

3.7. Research procedures

As mentioned earlier in section 3.3.2, DBR is systematic, interventionist and iterative in nature. It usually follows a design ↔ development ↔ enactment ↔ analysis ↔ reflection ↔ revision cyclic process which is discussed theoretically in section 3.3.2.

This study was carried out following this cycle in general and the three phases of the generic model (figure 3.2) of DBR (McKenney & Reeves, 2012) in particular. The nomenclature of the three phases of the generic model was changed to some extent to make it simple and a logical sense of the procedures to the reader. For instance, the first phase in the generic model of DBR is *Analysis and Evaluation* but in this research the designing of the intervention is also presented as a part of this phase. The nomenclature of the three phases adopted in this study is similar to that suggested by Cobb and Gravemeijer (2008). Cobb and Gravemeijer (2008) specify the three DBR phases as *preparing for the experiment*, *experimenting to support learning* and *conducting retrospective analysis*. Details of the activities conducted in the three phases are presented below.

3.7.1. Phase 1: Preparing for the experiment

The main aim of this phase is to identify, understand, define and diagnose the problem in the context, and to propose some tentative solutions in terms of design. A detailed analysis of the problem is carried out by studying its historical, political and contextual aspects such as curriculum, policy, pedagogy and practice. This phase usually includes a detailed literature review, formal and non-formal observations, old and immediate experiences and exploration of on-going practices in the educational context. Given the context of this research (section 1.2) as secondary school science and the identified problems of conceptual learning, science achievement and motivation towards science learning, this phase analysed the Indian national curriculum framework (INCF) recommendations and the instructional (teaching-learning-assessment) processes in practice. Informal observations by the researcher for five years, before this research was started, played an important role in identifying, and to some extent understanding, the problem of conceptual learning and motivation in secondary classrooms in terms of students' science achievement, attitudes and teacher practice. The science content in the textbooks and the methods of instruction (pedagogy) were discussed with colleagues and school teachers and a needs analysis was conducted to arrive at tentative solutions of the problem of learning and motivation. Based on these experiences, observations, discussions and recommendations, a detailed literature review (sections 2.1 to 2.4) was carried out to understand and explain the problem and to focus the research. Grounded in the literature review, some theoretical (such as collaborative learning and constructivism) as well as practical (such as existing models and interventions) solutions were considered, analysed and proposed to solve the problems of learning and motivation in secondary school science prevailing in the Indian classroom context. These theoretical and practical solutions were integrated to design the Computer-based Collaborative Concept Mapping (CCCM) intervention (section2.7) and to try it out in the context to solve the problem. The intervention was initially assessed in terms of the criteria of feasibility, focus (outcomes) and its practicality to inform the issues of conceptual learning and motivation. These criteria asked some basic questions such as- could it potentially be carried out in the classrooms as planned? Could it potentially lead to the type of knowledge and motivation that was anticipated by teachers? Could it potentially create an active, interactive and motivating learning environment? What challenges would it face? These criteria questions were reviewed after the first try-out (pilot testing) part of the next phase and informed the revision and refinement of the intervention.

3.7.2. Phase 2: The Teaching Experiment[12]

The main objective of a classroom teaching experiment is to study students' first hand learning experiences, to support and develop the learning process and to develop a domain specific theory of instruction (Cobb & Gravemeijer, 2008; Steffe & Thompson, 2000). A teaching experiment is usually carried out in collaboration with a teacher or group of teachers, and the researcher can also act as a teacher (Cobb, 2000). A teaching experiment can produce different and sometimes additional findings which randomized experiments cannot. For example, Cobb (2000) argues that a teaching experiment as an approach or methodology can provide a way of exploring possibilities of reform in the classroom. Additionally, in a collaborative situation, as is the case of the current research, a teaching experiment can inform the extent to which the collaborations (group work in this research) support the learning of students as well as teachers (Cobb, 2000; Cobb & Gravemeijer, 2008).

This enactment phase of the designed intervention in this study consisted of three main stages (sub-phases). In DBR literature these stages are usually termed as iterations or

[12] Teaching experiment is a widely accepted and used term in DBR studies which differentiates it from other methods such as randomized experiments and action research. For more details see Steffe and Thompson (2000), Cobb (2000) and Cobb and Gravemeijer (2008).

micro and meso[13] cycles. In the first stage of the teaching experiment the intervention (CCCM) was pilot tested to ensure its success in actual classroom environments. The second stage after the pilot testing revised, refined and evaluated the intervention for its workability and added effectiveness in the classrooms. Finally, the third stage involved the actual teaching experiment which lasted for 10 weeks. These three sub-phases are reported in brief in the following sub-sections.

3.7.2.1. Pilot testing

The designed intervention was pilot tested in a different school to the intervention schools of the study. Informed consents were sought from the school principal, the teacher and students involved. Two meetings were held with the teacher to explain the research purpose and focus, and to get familiarity with the intervention and software used. The classroom teacher and students were separately trained by the researcher to use the intervention in practice. The intervention was piloted with 10 students for two weeks (including training, evaluation and reflection time). The intervention was evaluated in terms of students' understanding of science concepts and attitudes towards its use. The participating teacher was also asked to reflect on the process and experience. Some of the research tools such as the achievement test, motivation questionnaire, concept maps, and teacher interview (section 3.6) were used to generate and examine the findings from this feasibility study.

3.7.2.2. Evaluation, revision and refinement

A detailed analysis and evaluation of the pilot-tested intervention was carried out after two weeks. The intervention was re-designed after the pilot and before it was ready to be implemented in the selected science classrooms. Based on the outcomes of the pilot testing, many aspects of the intervention and research were reviewed. For example, the concept of conceptual learning was made explicit in terms of Higher-order Cognitive Skills (HOCS) and Lower-order Cognitive Skills (LOCS) to define conceptual learning functionally and to focus the outcome of the intervention. The collaboration aspect of the intervention was reviewed to emphasise peer interaction, support and accountability. Some challenges arose in group work, such as competition, argumentations and

[13] The word meso is derived from the word 'mesos' in Greek language which means middle or intermediate. In scientific terminology micro, meso and macro words are used to indicate very small, medium and very large scales of measurements.

meaning negotiation. These were thoroughly explored and settled based on additional literature. The ground rules (appendix A) for the implementation of CCCM were established to avoid and minimise the issues faced. During the pilot testing, both students and teachers reported positive attitudes towards the use of CCCM in their classrooms. The teachers commented that it could enhance students' conceptual learning, motivation towards science learning and support teachers to develop professionally. A detailed reflective analysis was also done to ensure the feasibility and practicality of the intervention during the main experiment.

3.7.2.3. The main experiment

The third sub-phase (stage) of the teaching experiment phase of the research was carried out in the two science classrooms for 10 weeks. Formal consents were obtained from the school principal, teachers, students and parents before starting the experiment. The formal procedure to obtain informed consent (appendix G) included information sheets and consent forms. The information sheets explained the research focus, researcher's and participants' roles and participants' rights. After getting necessary consents from the school authorities, CCCM was then assigned to the two intervention (experimental) groups as indicated in the research design (figure 3.5) of the study. The previous science achievement scores were examined to establish the equivalence among the four groups. The two groups (A and B) were also pretested as per the *Solomon four-group* research design to assess students' learning and motivation levels.

Before the actual implementation of the intervention (teaching experiment), the two science teachers were trained for a week to make them familiar with the software and intervention. Then the intervention was introduced to students. Initially, students worked in small groups and practiced concept mapping and collaborative concept mapping on paper for two weeks in face-to-face situations. Students prepared paper-based concept maps, usually on chart papers, and discussed the maps in class. After becoming familiar with the idea of concept mapping, students shifted to the computer labs to use the intervention software. Figure 3.8 shows the two settings in which students practiced concept mapping in groups without the computer and during the main experiment. Although an additional iteration at the end of the academic session (after 6 months) was also planned it was dropped because of the time, efforts and distance between the research site and institution involved.

3.7.3. Phase 3: Evaluation and Reflection

In the third phase of the study a summative evaluation of the intervention was carried out in terms of the learning and motivation gains and experiences of participants. After the actual teaching experiment students were post-tested to assess their conceptual learning, science achievement and motivation levels. The main objective of the evaluation was to study the effectiveness of the intervention. The findings from the achievement tests, the SMTSL questionnaire and concept maps (evaluation tools; section 3.6) are presented in chapter 4.

The two science teachers and two groups of students were interviewed to investigate their perceptions and experiences of the CCCM use in their classrooms and to conduct a detailed reflective analysis of the intervention. Results of these interviews and focus group discussions are reported in chapter 4. Some of the reflections (in terms of interpretations and speculations) are also included in the discussion chapter 5.

1) Students practicing and studying without and with computer in school 1
2) Students studying science in groups using CCCM in school 2

Figure 3.8 Students practicing and studying science content using CCCM in intervention schools

3.8. Data analysis

The quantitative data analysis used descriptive as well as inferential statistical methods to make sense of the numbers obtained. The Statistical Package for Social Sciences (SPSS) was used to carry out the tests to check the statistical significance of the numerical differences obtained for science achievement and motivation. Quantitative data from the ATS9 and the SMTSL questionnaire were analysed to obtain results. The qualitative data in the form of students' individual and group work samples (concept maps) were analysed following the rubrics (appendices I and L) and set criteria. The interview and group interview data was thoroughly analysed using the computer-based NVivo software and thematic analysis. Details of each of these methods of data analysis are presented in the following sections.

3.8.1. Data analysis from Solomon four-group design

Although the Solomon four-group research design is considered to be a "highly prestigious" (Huck & Sandler, 1973, p. 54) experimental research design, it is seldom used in educational research due to its complicated statistical analysis (Sawilowsky, Kelley, Blair, & Markman, 1994). Campbell and Stanley (1966) state that there is no single statistical procedure to compare the six outputs obtained from four groups. Since this design is a combination of the 'pretest-intervention-posttest' and 'post-test' only designs, it involves multiple statistical analyses (for example ANOVA, ANCOVA, MANOVA and multiple t-tests). The method of analysis, thus, depends on the objectives of the research and intention of the researcher to explore the issues. From time to time, different researchers (for example, Braver & Braver, 1988; Campbell & Stanley, 1966; Huck & Sandler, 1973) have suggested different ways of analysing the data obtained from the four groups of the Solomon design. Huck and Sandler (1973) suggest that the four outcomes from the post-tests should be subjected to the 2x2 factorial ANOVA to see the effects of the pretests and the treatment (pretest-treatment interaction) at first, and then independent and paired t-tests should be carried out to study the statistical significance of differences among different groups.

A more logical and elaborated procedure called the 'meta-analysis approach' is suggested by Braver and Braver (1988) in the form of a flowchart (see figure 3.9) to analyse the differences among the means and variances. Because of its statistical power, this procedure has been adopted and applied to this study to explore the differences between achievement and motivation scores among the four groups and to examine the pretest-intervention interaction. Figure 3.9 displays a 5-step, step-by-step process as suggested by Braver and Braver (1988). The first and initial test is to perform a 2x2 ANOVA on the post-test outcome scores, viz. O_2, O_4, O_5, and O_6 of the four groups.

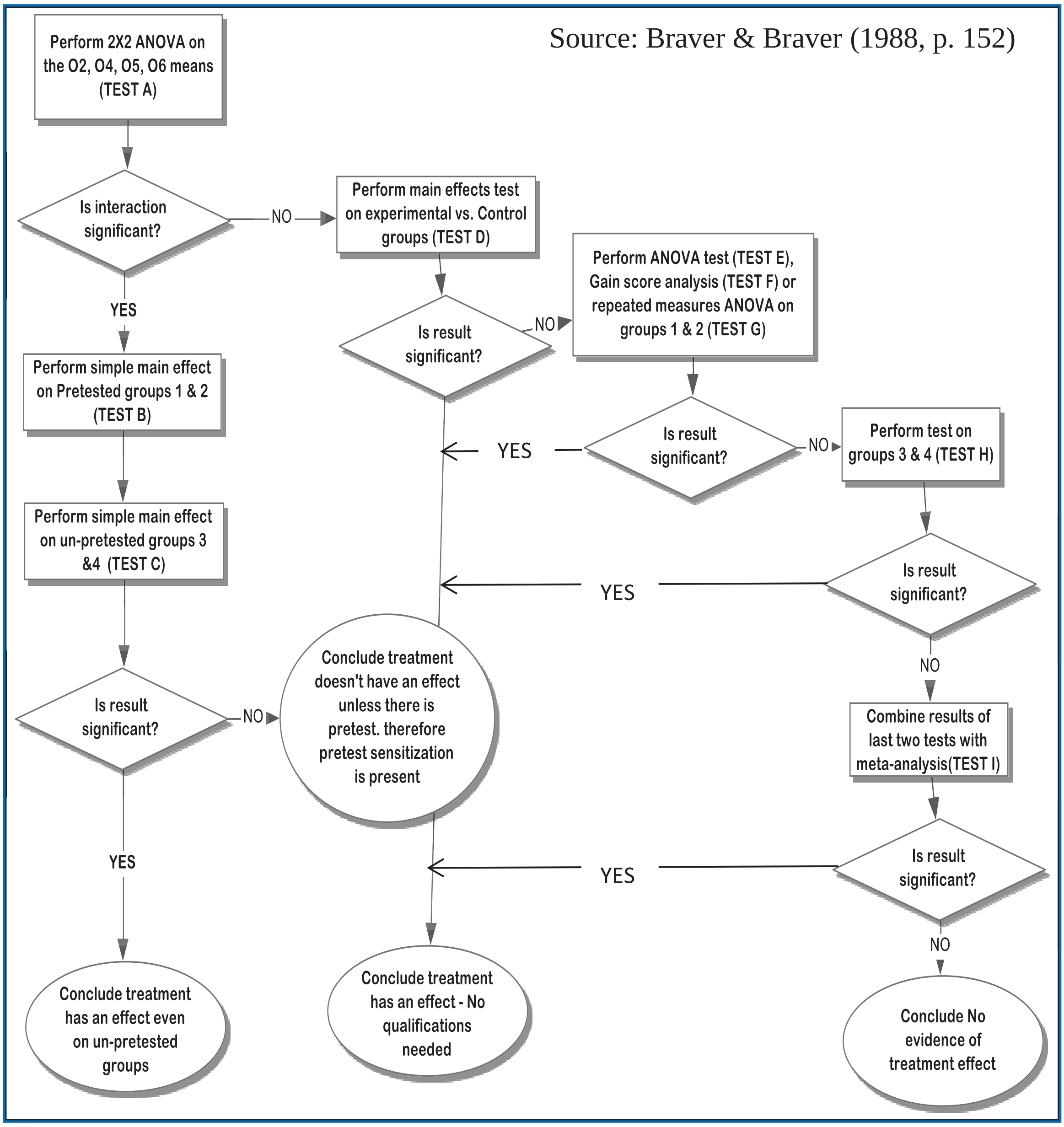


Figure 3.9 Statistical analyses for Solomon four-group design

The 2x2 ANOVA test, as indicated by 'Test A' in the diagram, tests the interaction of the pretest with the intervention applied. If the intervention-pretest interaction is found to be significant then simple main effects tests on the pretested groups (Test B) and on the un-pretested groups (Test C) are to be performed. The conclusion about the effect of the intervention is drawn based on the outputs of these tests. If the pretest-intervention interaction from the 2x2 ANOVA test is found to be insignificant, then outcome scores from the experimental and control groups are subjected to the main effects test for the intervention (test D). Other tests, depending upon the significance of the results found, span through the meta-analysis as suggested by Braver and Braver (1988). For the current study, the only tests performed were Test A and Test D, the outputs of which are presented in chapter 4.

3.8.2. Achievement test data analysis

The responses written by students on the ATS9 response sheets were scored according to the scoring norms (appendix I) and procedures. All the answers that include multiple choice answers, LOCS and HOCS were marked by assigning categories and their respective scores, which were finally added to measure a student's achievement in science. These scores were initially tabulated in the *Microsoft Excel* data sheets for the sake of saving an additional and safe copy, and finally entered to the SPSS data sets. Following the Braver and Braver (1988) procedure of data analysis these quantitative data (achievement scores) obtained from the ATS9 were analysed using SPSS software. Quantitative data were described in terms of means, variability co-efficient and graphs using descriptive statistics. The inferences were drawn from further treatment of data using different tests of significance, for example t-tests and ANOVA. Findings from the ATS9 scores are discussed in section 4.1 of chapter 4.

Another major purpose of administering the ATS9 was to assess students' levels of conceptual learning for the open ended questions. The 23 open ended items (appendix H) were assessed against the criteria developed in the rubric for assessment for ATS9 (appendix I). The responses written by students for the 13 LOCS category questions were assessed against the first three categories of *Proficient, Intermediate and Novice*, while the responses for the remaining ten HOCS items were assessed against all the four categories of *Advanced, Proficient, Intermediate* and *Novice*. The main reason for using similar rubrics for assessing the LOCS and HOCS items was the cognitive processes involved in answering them. A LOCS item does not usually require the respondent to use higher order skills of analysis, synthesis and evaluation, while to answer a HOCS item the respondent is supposed to use all these cognitive processes. The data obtained for the LOCS and HOCS items were also analysed in terms of descriptive and inferential statistics, and are presented in section 4.2 in chapter 4.

3.8.3. Concept map data analysis

Concept maps constructed by students in groups on different science topics were analysed according to the concept map analysis rubric (appendix L). These concept maps were assessed and reported using the three categories of *Proficient, Intermediate* and *Novice*. The concept map rubric was designed after analysing and evaluating different, already existing, techniques of quantitative and qualitative analysis of concept maps. Some selected concept maps were analysed by associating them with ATS9 responses obtained for the group members who constructed the map. This association and comparison of ATS9 answers with the group concept maps provided important information about individual students' levels of conceptual learning and the group's conceptual learning.

3.8.4. The SMTSL questionnaire data analyses

The quantitative data obtained from the SMTSL questionnaire were analysed using statistical methods (the SPSS). The coding and scoring was done according to the procedure suggested by Tuan et al. (2005) to ensure the validity of results. For example, scores for the reverse items were transformed to ensure the legitimacy of the results. The scores were then entered in the *Microsoft Excel* sheets and later transferred to the SPSS data sets for descriptive and inferential analyses. Data were described in terms of means and variations, and using graphs. A range of ANOVA and t-tests, as suggested by Braver and Braver (1988), were conducted to compare different groups for overall motivation scores as well as scores obtained for the six scales of the SMTSL questionnaire. The findings from the SMTSL data analyses are presented in section 4.3 in chapter 4.

3.8.5. Analysis of interview and focus group data

The audiotaped teachers' interviews and videotaped students' focus group discussions were transcribed following the procedure suggested by Bailey (2008). Bailey discusses the process of data transcription in terms of choosing the relevant verbal information and omitting the irrelevant information such as the non-verbal dimension. In suggesting so, Bailey also warns the reader to make decisions based on the specific goals of research and the level of detail required. The coding protocols were developed to differentiate the different types of data and to avoid mixing of the information. Pseudonyms were assigned to ensure the confidentiality and anonymity of the participants. The identifiers to identify the interview and FGD findings such as *Lata-Tr2Sch2Int* and *GpASch1FGD* which could locate the participants were developed. For instance, the first identifier just mentioned indicates the teachers' pseudo name, number, the school and the type of data source tool. Similarly, the second example denotes the name and number of the sub-group, school, and the data tool. Special identifiers for the focus group discussion such as *[WORD]* for confusion or noise, and such as *[sir, it is a better method…]* to denote the overlapping of different voices and to add researcher's comments were also developed. The transcriptions of the teacher interviews were sent to the teachers for their approval and additional remarks to ensure the validity of information.

After getting the interview and FGD data in electronic format, data coding was done to identify different themes and issues of interest. The coding process usually involves assigning labels, tags or names to the information of interest. Coding generally requires many cycles of reading and re-reading to get the essence and real sense of the depth and breadth of the responses (Punch & Oancea, 2014). Information from different parts of the interview, sometimes need to be grouped according to the codes and themes. Required and important information from the interviews was listed according to the themes and sub-themes related to the research questions. As Gill et al. (2008) warn the FGD data analysis can be complex and time consuming because of the interaction involved, the FGD data was analysed in a systematic way. The speakers were identified from the video recordings and the videos were transcribed exactly as spoken. Finally, this information was interpreted keeping in mind the overall educational context, individual speakers' perspectives and context, and group dynamics as suggested by Gill et al. (2008).

3.9. Ethical considerations

In addition to the philosophical aspects (ontology, epistemology and methodology; discussed in section 3.2) of a research study, Mertens (2015) stresses an important aspect, which is to ask the axiological question: "What is the nature of ethics?" (p. 10).

Axiological questions of any research are related to the ethics or values that a researcher considers important and puts stress on when carrying out a study. Punch and Oancea (2014) define ethics as “the study of what are good, right or virtuous courses of action” (p58). These ethics are an integral part of any research and should be acknowledged in the planning and conducting of any research, no matter what methods/paradigm a researcher uses (Mertens, 2015). Usually, these ethics are the expressions of basic human rights of respect for person, autonomy, justice and privacy of the research participants (Massey University, 2015). A researcher of social sciences has to address ethical issues related to the participants and their context, such as cultural, communal and religious, to add to the credibility of their research. Ethical issues may arise starting from the outset (planning) to the conduct and evaluation of any research project (Punch & Oancea, 2014). Keeping in mind the need and importance of addressing these issues, research councils, committees, and institutional review boards have identified different ethical principles to guide research practice. These principles generally are reported as the codes of ethical conduct for the associated researchers. Prominent examples of educational research related codes are the American Educational Research Association’s (AERA) (2011) code of ethics and the Australian Association for Research in Education’s (AARE) (2016) code of ethics. These codes present comprehensive lists of values and principles (general and specific) to guide the research behaviour of their members.

Massey University (2010, 2015) through its *Human Ethics Committee* (MUHEC) administers an ethical code of research titled *Code of ethical conduct for research, teaching and evaluations involving human participants*, which was followed during the planning and conduct of this research. The following points discuss the consideration of the eight ethical principles outlined in the MUHEC code of conduct in relation to the conduct of this research:

1. *Respect for persons:* The principle states that the personal dignity, rights, beliefs, privacy and autonomy of participants should be ensured. The participants have the right to decline to participate and for that they need not give any reasons (Massey University, 2015). To address this principle, every participant was given due respect for deciding to participate or not, and to withdraw from the study. Before that, every gatekeeper (Punch & Oancea, 2014) (The Director Public

Instruction-DPI, District Education Officer-DEO and school principal, in this case) was given due respect to allow (or not) the researcher to carry out the study, keeping in mind the complexities involved in those decisions.

2. *Minimization of risk of harm:* Every possible form of harm, such as physical, social, psychological, reputational, practical, occupational and economic (Punch & Oancea, 2014) harm, to everyone involved or related to the study was diminished by ensuring the minimization of pain, fatigue, stress, emotional distress, exploitation, embarrassment, and cultural dissonance (Massey University, 2015). For example, students were made comfortable while introducing the intervention and were encouraged to share any doubts or worries. Separate and equivalent class arrangements were made for non-participating students with the help of teachers and school principals. Additionally, every potential risk of harm to the researcher, community, groups and Massey University was considered and minimized.

3. *Informed and voluntary consent*: Clark (1997) stress that in order to carry out a research project, the researcher needs to obtain *informed* consent and not just the consent from the participants. The agreement of participants should be based on decisions made by them on the basis of detailed knowledge and information provided to them about the research and their roles and expectations (Clark, 1997). In this research, sufficient information about the study was provided to the authorities and participants to obtain their informed and voluntary consent (appendices C, D, E and G). Given the average age of 15 years of the student participants, their parents were contacted to obtain their consent (appendix F) to participate in the research, informing them of the students' rights of anonymity, confidentiality, privacy and withdrawal from the study at any time (Creswell, 2012).

4. *Respect for privacy and confidentiality*: The privacy of the students in public places other than classrooms and computer labs, such as during assessments and discussions, was ensured and stated very clearly when obtaining informed consent. Participants were made aware of the confidentiality of the information collected and its use. The principle of respect for persons (Clark, 1997; Punch &

Oancea, 2014) was addressed by ensuring the non-disclosure of information to third parties and its storage at a safe place.

5. *Avoidance of unnecessary deception*: In some research projects, for instance in a psychological study, obtaining informed consent is impossible or undesirable depending upon the aims and larger benefits to the community (Massey University, 2015). In those cases, deception should be justified and clearly stated to the ethics committee. Given that the primary purpose of the present study was to improve the learning, motivation and achievement of students in secondary science and this was clearly stated in all the communications with participants, the potential scope of deception in carrying out of this research was nil.

6. *Avoidance of conflict of role/interest*: In educational or social research, sometimes a conflict of interest may arise due to the positions, roles and benefits to different parties. This research was not funded by any organisation and the position of the researcher as a PhD student and previous teacher did not cause any conflict with any party involved in the research process. None of the research participants were previously known to the researcher. Every possibility of any conflict and its nature between roles and interests of the researcher was identified to the MUHEC when seeking approval for the conduct of this study. The roles of the researcher (as teacher trainer, facilitator, researcher) and activities (such as assessment) carried out by the researcher during the project were outlined and explained to minimize and avoid any conflict of interest with participants and institutions. However, no conflict of interest was identified during the carrying out of this study.

7. *Social and cultural sensitivity*: The MUHEC code of conduct (Massey University, 2015) outlines the two types of communities to which the researcher is accountable: the academic and the ‘community’ in which the actual research is carried out. A researcher is answerable to the academic community in that the head of the college/institute/school/committee or supervisors’ reviews and peer review should be carried out to ensure the legitimacy of the research (Massey University, 2015). Social and cultural sensitivity can be ensured by giving respect to indigenous participants, seeking their permission and support beforehand, taking into account their system of beliefs and collaborating with the

participating community to share the benefits and ownership of the project (Massey University, 2010, 2015). Every aspect of the social and cultural identity of participants and overall educational context was considered before the start of this research. Given the equivalent social status of all the participants, there was none to be identified as socially and culturally different. The cultures of the researcher and the participants were also alike.

8. *Justice*: According to Clark (1997) the utility of a research project can be considered in terms of better understanding of an educational issue, the benefits to the body of knowledge, benefits to the community and participants and finally to the researcher in terms of funding, promotion, qualification, commercial or political. Clark (1997) warns that a researcher’s benefits should not over-ride the community, participants and the field. In this study, the purpose of research was made clear to all concerned and involved. Apart from gaining the degree the main purpose of research was to improve the pedagogy, instruction and learning practice, along with the achievement and motivation of secondary school students to learn science. Therefore, the findings were in the interest of the community and the participants in the first instance (Clark, 1997) and others later on.

Keeping in mind researchers’ broad responsibilities (American Educational Research Association, 2011; New Zealand Association for Research in Education, 2010) and the MUHEC code of ethics (Massey University, 2010), an initial assessment of the Massey University screening questionnaire to determine the low/high risk notification was carried out. This process was carried out in consultation with the main and co-supervisor. The outputs of the screening questionnaire and the nature of research (the methodology and methods) indicated that this study required a low risk notification from the MUHEC. Therefore, an application for the low risk notification was made to the MUHEC to obtain permission for carrying out the study. The approval letter from the chair of MUHEC is attached in the appendix B.

After MUHEC approval, the Director Public Instruction of Schools (DPI Schools) and heads of the schools were contacted to seek permissions to carry out the study in the anticipated Indian schools. Copies of the letters, consent forms and approval are attached in appendices C and D. Finally, the school teachers, students and parents were contacted to seek their consents to participate in the study. The letters to teachers, parents and students along with the consent forms are attached in appendices E, F and G.

This chapter presented the theoretical aspects of research methodology and discussed its situation in the pragmatist paradigm. The use of the design-based research as an appropriate methodology for this study was discussed and justified. After that, the Solomon four-group research design adopted to carry out the study was explained and justified. The research procedures were then described followed by a discussion of the process of data gathering and analysis. Finally, the ethical issues related with the research were considered and addressed in practice. The results obtained from the data analyses are presented in chapter 4.

Chapter Four. Results

The purpose of the study was to investigate the effectiveness of computer-based collaborative concept mapping (CCCM) on Indian secondary students' science achievement, conceptual learning and motivation towards science learning. The results obtained from the analyses of the data are reported in this chapter. The results are presented in the same sequence as of the research questions. The initial sections 4.1 and 4.2 present the quantitative and qualitative descriptions of results for students' achievement and conceptual learning in science obtained from the ATS9 and concept maps. The results for the motivation questionnaire (SMTSL) are presented in section 4.3. The subsequent sections 4.4 and 4.5 then present findings from the teacher interviews and students' focus group discussions. A limited description of results is given here, whereas a detailed discussion is provided in chapter 5.

4.1. CCCM and science achievement

As described in chapter 3, the Achievement Test in Science for grade 9 (ATS9) was administered as a pretest and posttest as outlined by Solomon four-group research design (see figures 3.5 and 3.6). This test was designed with dual purposes in mind. The ATS9, in the first instance, assessed the student participants for their overall science achievement. In the second instance, the ATS9 provided a tool to assess the levels of students' conceptual understanding of science concepts. The data obtained from the ATS9 posttests and pretests were analysed according to the scheme (see figure 3.9) suggested by Braver and Braver (1988). The results obtained by administering the statistical tests suggested by Braver and Braver (1988) are given in the following sub sections.

4.1.1. Equating the four groups

One of the major assumptions of the *Solomon four group research design* is that the four groups should be equivalent in terms of the dependent variable before the administration of the intervention (Mertens, 2015). To examine the equivalence of the four groups (classrooms) for science achievement in this study, one-way ANOVA was carried out on the previous year's (grade 8) final examination scores. The previous year's examination scores of students were requested from the school offices. The results obtained from the one-way ANOVA are displayed in Tables 4.1 and 4.2. The three major assumptions of ANOVA (Field, 2009)- the *normality* of the dependent variable (achievement in this case), the *homogeneity* of the variance among the four groups and the *independence* of observations were met before administering the ANOVA test. The results for Leven's test: F (3, 237) = 0.67; p = 0.59, indicated that the difference between variances among the four groups is not significant and therefore, the variances in the groups can be considered homogeneous.

A one-way ANOVA was administered on the previous year's examination (grade 8) scores to examine the differences in science achievement of the four groups. The difference amongst the previous year's achievement scores as determined by the one-way ANOVA was not found to be statistically significant (F (3, 237) = 1.49, p = 0.28). Therefore, the four groups can be considered equivalent in terms of science achievement based on the previous year's examination scores. These results simply mean that the four groups did not differ on grade 8 science achievement and were equal before the intervention. Table 4.1 shows the descriptive statistics for the four groups.

Table 4-1 *Descriptive statistics for the one-way ANOVA*

Dependent variable: Science Achievement (previous year)				
Groups	N	Mean	SD	Std. Error
Group A	57	45.49	5.49	.73
Group B	55	43.85	6.13	.83
Group C	67	44.04	6.19	.76
Group D	62	42.89	6.72	.85
Total	241	44.01	6.18	.39

Additionally, the output from the multiple comparisons table of Tukey's post hoc test (Table 4.2) suggested that the achievement between any of the groups did not statistically differ (see *p* values in the last column of Table 4.2). The non-significant *p* values (*p* = 0.498, 0.563, 0.165) suggest that the difference between the mean of group A and the other three groups B, C, and D is not statistically significant. Similarly, the non-significant *p* values (*p* = 0.498, 0.998, 0.925) suggest that the difference between the mean of group B and the other three groups A, C, and D is not statistically significant. The other two rows of the results for groups C and D also suggested the same. Therefore, all four groups can be considered equivalent in terms of achievement at the onset of the research project.

Table 4-2 *Results for multiple comparisons table (Tukey post hoc test)*

(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	Sig.
A	B	1.637	1.165	.498
	C	1.446	1.111	.563
	D	2.346	1.131	.165
B	A	-1.637	1.165	.498
	C	-.190	1.122	.998
	D	.709	1.142	.925
C	A	-1.446	1.111	.563
	B	.190	1.122	.998
	D	.900	1.086	.841
D	A	-2.346	1.131	.165
	B	-.709	1.142	.925
	C	-.900	1.086	.841

Moreover, to equate the two pretested groups (A and B) according to the *Solomon four group research design* (figure 3.5), an independent samples t-test was administered on the pretest scores obtained from the ATS9. The results obtained from the t-test are shown in Tables 4.3 and 4.4. Table 4.3 displays the descriptive statistics obtained to describe the nature of the results obtained for the t-test on pretest achievement scores in terms of the means, standard deviations and standard errors of the two group means.

Table 4-3 *Descriptive statistics for the independent samples t-test*

Dependent variable: Science Achievement (pretests)				
Groups	N	Mean	Std. Deviation	Std. Error Mean
Intervention	57	4.50	2.33	.32
Comparison	55	4.59	2.39	.34

The results obtained from the independent samples t-test are presented in Table 4.4. The first two columns of Table 4.4 display the results for Levene's test which is to check if the variances among the two groups are homogeneous or not. The *F* value of 1.07 and the non-significant *p* value of 0.30 from tLeven's test suggest that the variances among the intervention and comparison groups are equivalent. Therefore, the assumption of homogeneity is met.

Table 4-4 *Results for the independent samples t-test*

Independent Samples Test						
Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
1.07	.30	-.19	110	.85	-.09	.46

The next columns of Table 4.4 show the results for the independent samples test for the intervention and comparison groups' pretest scores. The results obtained for the t-test can be presented as:

> An independent-samples t-test was conducted to compare the pretest achievement scores for the intervention and comparison group students. The difference between the achievements of the intervention group (*M* = 4.50, *SD* = 2.33) and comparison group (*M* = 4.59, *SD* = 2.39) was found to be not statistically significant; t (110) = -0.19, p = .85.

Therefore, on the basis of these results, it can be concluded that there is no significant difference between the pretest achievement scores of the intervention group A and the comparison group B students. In other words, the independent sample t-test confirmed the equivalence of the two pretested groups A and B, and hence the assumption of equivalence of the participating groups before the intervention was met.

4.1.2. The 2x2 factorial ANOVA test

To examine the effects of the intervention and pretesting of the two groups on science achievement, the data obtained from the ATS9 posttests for the four groups (A, B, C and D) were analysed according to the scheme (Figure 3.9) suggested by Braver and Braver (1988). The first step of the scheme suggested carrying out a factorial 2 x 2 ANOVA test. The factorial ANOVA is generally performed to examine the interaction of two or more independent variables with the dependent variables in a study. In this case, the objective was to study the interaction between the two independent variables: the intervention and the pretest. The dependent variable was students' achievement scores on posttests ATS9. The six assumptions of the factorial ANOVA- *continuity* of the dependent variable, presence of two or more *categorical independent variables*, *independence* of observations, absence of *significant outliers* in the dependent variable, *normality* of the dependent variable and the *homogeneity* of variances- as suggested by Field (2009) were met before carrying out the ANOVA test. The results of the 2x2 ANOVA (test A) are displayed in Table 4.5.

Table 4-5 *Results for the 2x2 ANOVA test*

Tests of Between-Subjects Effects, Dependent Variable: Achievement in science					
Source	Type III Sum of Squares	df	Mean Square	F	Sig. (p-value)
Pretest (between pretested and un-pretested groups)	6.86	1	6.86	.225	.635
Intervention (between Intervention and Comparison Groups)	878.42	1	878.42	28.88	.000
Pretest * Intervention (interaction)	73.74	1	73.74	2.43	.121

The results obtained from the 2x2 ANOVA (Table 4.5) can be interpreted as follows:

The result for the interaction of pretests with the intervention is shown in the last row of Table 4.5, which indicates an F value equal to 2.43. As the F value is the ratio of two mean square values, it must be close to 1 to accept a null hypothesis. The larger the F value, the higher are the chances of rejection of null hypothesis. The p value of 0.121 is not significant and thus indicates the absence of any interaction of pretests with the intervention. However, the p value results for the pretest (p = .635) and intervention (p = .000) in column 6 of Table 4.5 suggest that the difference between the achievement scores of the pretested and un-pretested groups is not significant, whereas the difference between the intervention and comparison groups is significant. The non-significant value of p for pretest (p = .635) indicates that pretest sensitization is not present, which in other words means that the administration of the pretest did not interfere with the intervention to affect the achievement scores on the posttests. Therefore, according to the flowchart by Braver and Braver (1988), the results are subjected to further statistical analysis for calculating the main effects of the intervention (Test D; Figure 3.9).

4.1.3. Main effects of the intervention

The simple main effect of the intervention was calculated on the basis of the difference between the joint means of the intervention groups (A and C) and the comparison groups (B and D). In other words, the main effects of the intervention are determined by the significance of the difference between posttest means (A+C)/2 and (B+D)/2 of the intervention and comparison groups. All the basic assumptions of the independent samples t-test (such as *independence* of observations, *continuity* of the scores and *normality* of the distribution), except the *homogeneity* of variance, were met. The descriptive statistics and the results of the effect of the intervention obtained from the independent samples t-test are presented in Tables 4.6 and 4.7.

Table 4.6 shows the descriptive statistics results for the intervention and comparison groups in terms of the group samples (N), group means for science achievement, and standard deviations from the means and the standard errors of the means.

Table 4-6 *Descriptive statistics for the independent samples t-test*

Dependent variable: Science achievement (posttests)				
Groups	N	Mean	Std. Deviation	Std. Error Mean
Intervention	111	22.14	6.11	0.58
Comparison	107	18.05	4.84	0.47

The results obtained from the effect of the intervention test are displayed in Table 4.7. The first two columns of Table 4.7 show the results for Levene's test which is to check if the variances among the two groups are homogeneous (equivalent) or not. The *F* value of 7.52 and the significant value of $p = 0.007$ of this test suggest that the variances among the intervention and comparison groups are not equivalent. This indicates that the assumption of homogeneity of variances is not met. Therefore, according to the rule the values of the last row of Table 4.7 (*equal variance not assumed*) from the SPSS result output table are presented.

Table 4-7 *Results for the main effects of intervention test*

Dependent variable: Science achievement (posttests)						
Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
7.52	.007	5.46	216	.000	4.09	0.75
Equal variance not assumed		5.49	208.24	.000	4.09	0.75

The next columns of Table 4.7 show the results for the independent samples test for the intervention and comparison groups. The interpretation of the results obtained for the main effect of the intervention test is presented as below:

> An independent-samples t-test was conducted to compare the achievement scores for the intervention and comparison group students. There was a statistically significant difference in scores for intervention group (*M* = 22.14, *SD* = 6.11) and comparison group (*M* = 18.05, *SD* = 4.84; *t* (208.24) = 5.48, *p* = .000).

The magnitude of the differences in the means (mean difference = 4.09, 95% Class Interval: 2.62 to 5.56) was calculated to be large (Cohen d (α) = 0.74; d = 0.8 for large, 0.5 for medium and 0.2 for small). According to Ellis (2010) an interpretation of the obtained Cohen's d value suggest that about 77% (CohenU_3) of students in the intervention group (CCCM) achieved above the mean of the comparison group students. In other words, an average intervention group participant outperformed 77% of the comparison group students.

Therefore, the null hypothesis H_{o1}: *CCCM does not affect science achievement of Indian secondary students*, is rejected. Hence, the intervention- computer-based collaborative concept mapping (CCCM) - has a positive effect on the science achievement of intervention group students. Moreover, the effect size of 0.74 suggests that the magnitude of the difference between the achievements is large.

4.2. CCCM and conceptual learning

As mentioned in section 3.6.1, another purpose of administering the ATS9 was to examine levels of students' conceptual learning in science. It is important to restate that conceptual learning for this study was defined in terms of only two dimensions of knowledge: conceptual and procedural knowledge. The other two dimensions viz. the factual and meta-cognitive knowledge were not included because of the focus and scope of this research. Answers written by students on ATS9 answer sheets were assessed for conceptual learning in terms of lower-order cognitive skills (LOCS) and higher-order cognitive skills (HOCS), and according to the assessment criteria and categories established by the ATS9 assessment rubric (see appendix I). The main reason for analysing LOCS and HOCS qualitatively was to triangulate some of students' responses with the concept maps prepared by them in groups. In other words, to carry out a comparison between student's individual conceptual learning and group learning. Out of the 35 questions in the ATS9, answers for 23 open ended questions were analysed to explore conceptual understanding of science concepts by students. These answers provided important information about levels of conceptual understanding and misconceptions held by students. The results are reported separately for questions that assessed LOCS and HOCS. Thirteen out of the 23 open ended questions aimed to assess LOCS of recalling of definition, facts, terminology, simple understanding of the concepts and simple reasoning for a scientific process. These 13 items therefore assessed conceptual learning against the last three categories of *Proficient*, *Intermediate* and *Novice* of the ATS9 assessment rubric. The remaining 10 items assessed HOCS which comprised of the application of conceptual knowledge, explicit and thorough understanding of the concepts, theories, models and principles, analysis of the problem, evaluation of the information, and scientific reasoning and articulation. The fourth category of responses from the ATS9 assessment rubric, namely *Advanced*, was therefore considered for the assessment of these answers. For details of the explanation and nature of these response categories refer to appendix I.

4.2.1. Results for questions that assess lower-order cognitive skills

The answers for the 13 LOCS questions written by students were assigned the scores 1, 2 and 3 for the *novice*, *intermediate* and *proficient* categories respectively. The scoring for the LOCS assessing questions was done separately by adding the scores assigned to the answers provided by the students of the intervention and comparison groups. An independent samples *t*-test was administered on the total LOCS scores to study the difference of conceptual understanding scores between the intervention and comparison group students. Similar to the main effects of intervention (section 4.1.3), to examine the precise effect of the intervention on conceptual learning, the two intervention groups A and C and the two comparison groups B and D were combined together to make one each of the intervention and comparison groups. The results obtained from the independent samples *t*-test are displayed in Tables 4.8 and 4.9.

Table 4.8 shows the descriptive statistics results for the intervention and comparison groups in terms of the group samples (N), group means for conceptual understanding scores, and standard deviations from the means and the standard errors of the means.

Table 4-8 *Descriptive statistics for the independent samples t-test for LOCS*

Group statistics (Dependent variable: Conceptual learning scores for LOCS)				
Groups	N	Mean	Std. Deviation	Std. Error Mean
Intervention	111	29.49	6.12	.580
Comparison	107	25.50	7.12	.688

The results obtained for the effect of the intervention test are displayed in Table 4.9. The first two columns of Table 4.9 show the results for Levene's test which is to check if the variances among the two groups are homogeneous (equivalent) or not. The *F* value of 9.02 and the significant value of $p = 0.003$ of this test suggest that the variances among the intervention and comparison groups are not equivalent. This indicates that the assumption of homogeneity of variances is not met. Therefore, according to the rule the values of the last row of Table 4.9 (*equal variance not assumed*) from the SPSS result output table are presented. The next columns of Table 4.9 show the results for the independent samples *t*-test for the intervention and comparison groups. The interpretation of the results obtained for the main effect of the intervention test is presented as below:

> An independent-samples *t*-test was conducted to compare the conceptual learning scores for the intervention and comparison group students. There was a statistically significant difference between scores for the intervention group ($M = 29.49$, $SD = 6.12$) and the comparison group ($M = 25.50$, $SD = 7.12$; $t\ (208.72) = 4.44$, $p = .000$).

The results of the *t*-test for conceptual learning suggested that the intervention-computer-based collaborative concept mapping (CCCM)- has a positive effect on the conceptual learning of the intervention group secondary school students. Therefore, the null hypothesis H_{o2}: *CCCM does not affect conceptual learning of Indian secondary students in science,* is partly rejected.

Table 4-9 *Results for the independent samples t-test for LOCS*

Dependent variable: Conceptual learning scores (posttests)						
Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
9.02	.003	4.44	216	.000	3.98	.898
Equal variance not assumed		4.42	208.72	.000	3.98	.900

To describe the nature and levels of conceptual learning, cohorts of students who demonstrated their conceptual learning according to the three categories of *proficient, intermediate* and *novice* in the intervention groups were compared with those in comparison groups. Table 4.10 provides of the results for the intervention and comparison group students in terms of percentages for the three response categories. A visual description of the percentages data from the Table 4.10 is presented in appendix P. The percentages of responses under each category provide a simple comparison of the numbers of responses between the intervention and comparison groups. The first column of Table 4.10 shows the corresponding question number on the ATS9.

An observation of Table 4.10 indicates that the percentages of answers for the *proficient* category are higher for the intervention group than that of the comparison group students. This trend in simple terms means that there are proportionally more students in the intervention group who demonstrate better conceptual understanding than in the comparison group. A reverse pattern for percentages of responses can be seen for the *novice* category of responses. It is interesting to notice the large variations in percentages of responses for *intermediate* category, because of the nature and difficulty level of the question. But overall, a combination of the percentages of intermediate and proficient categories show higher proportions for the intervention group than that of the comparison group. Some sample questions and answers are presented below to illustrate this pattern of percentages in a clearer way.

Table 4-10 *Percentages of responses for questions those assess LOCS*

Question number in ATS9	Percentage of responses					
	Proficient		Intermediate		Novice	
	Int.* Group	Comp.** Group	Int. Group	Comp. Group	Int. Group	Comp. Group
11	42	14	41	62	17	24
13	35	21	56	58	9	21
17	23	17	61	52	16	31
18	34	19	48	37	18	44
19	19	9	64	55	17	36
20	44	27	49	57	7	16
21	65	40	27	42	8	18
25	57	22	31	53	12	25
27	83	65	8	19	9	16
28	66	60	23	21	11	19
31	24	13	45	44	31	43
32	26	19	49	36	25	45
35	16	5	78	58	6	37

Notes: Int. *: Intervention, and Comp.**: Comparison

For example, question number 11 on the ATS9 aims to reveal students' understanding of the difference between an atom and a molecule. Answers obtained for this question indicated that 42 % of intervention group students are placed in the *proficient* category whereas only 14 % from the comparison group attained the *proficient* grades. The percentages for the i*ntermediate* and *novice* categories for the intervention and the comparison groups are 41, 62 and 17, 24 respectively. Sample answers for item 11 written by some students for three different categories are displayed in Figures 4.1, 4.2 and 4.3.

A *proficient* category sample of answer to question 11 is shown in Figure 4.1. This response indicates a clear explanation of the main difference between an atom and a molecule in terms of the use of keywords such as ‘chemically bonded’ and ‘attractive forces’, which was not very common in the responses obtained from comparison group students.

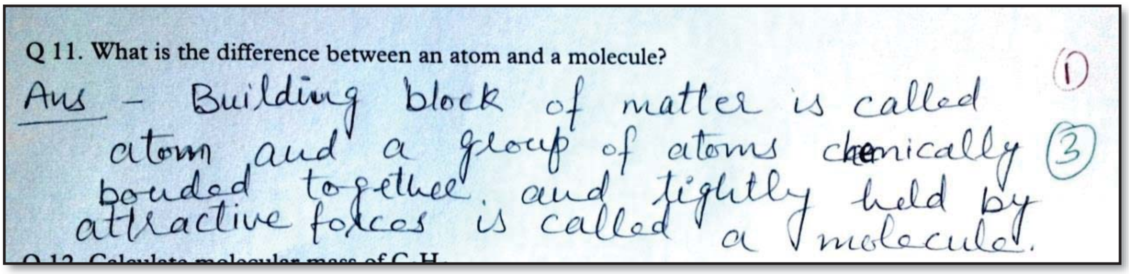

Q 11. What is the difference between an atom and a molecule?
Ans – Building block of matter is called atom and a group of atoms chemically bonded together and tightly held by attractive forces is called a molecule.
(1)
(3)

Figure 4.1 A sample answer for the *proficient* category for item 11

An *intermediate* category answer obtained for question 11 is given in Figure 4.2. Although the response indicates some confusion of the student, the provided explanation makes some sense so the response is placed in the *intermediate* category.

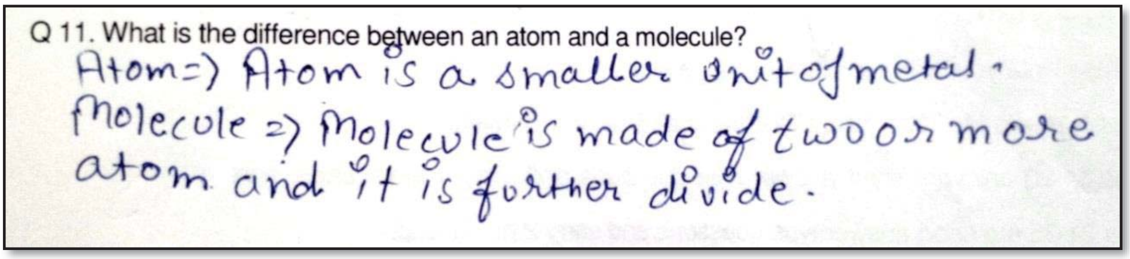

Q 11. What is the difference between an atom and a molecule?
Atom=> Atom is a smaller unit of metal.
Molecule => Molecule is made of two or more atom and it is further divide.

Figure 4.2 A sample answer for the *intermediate* category for item 11

Some *novice* category answers to question 11 obtained were similar to the samples given in Figure 4.3. Both of the *novice* category responses in Figure 4.3 indicate faulty conceptions of the differences between an atom and a molecule. Both students demonstrate incorrect definitions of an atom and a molecule and that is the reason they find it hard to differentiate them explicitly. The first answer in Figure 4.3 reveals poor understanding stating that molecule is present in an atom, whereas, the second answer states that an atom is equal to 1/12th of the carbon atom. Although, during the intervention period, a focus and stress was on the correction of these misconceptions, only the presence of such misconceptions is described in this study and a detailed analysis and correction of these misconceptions is beyond the scope of this research.

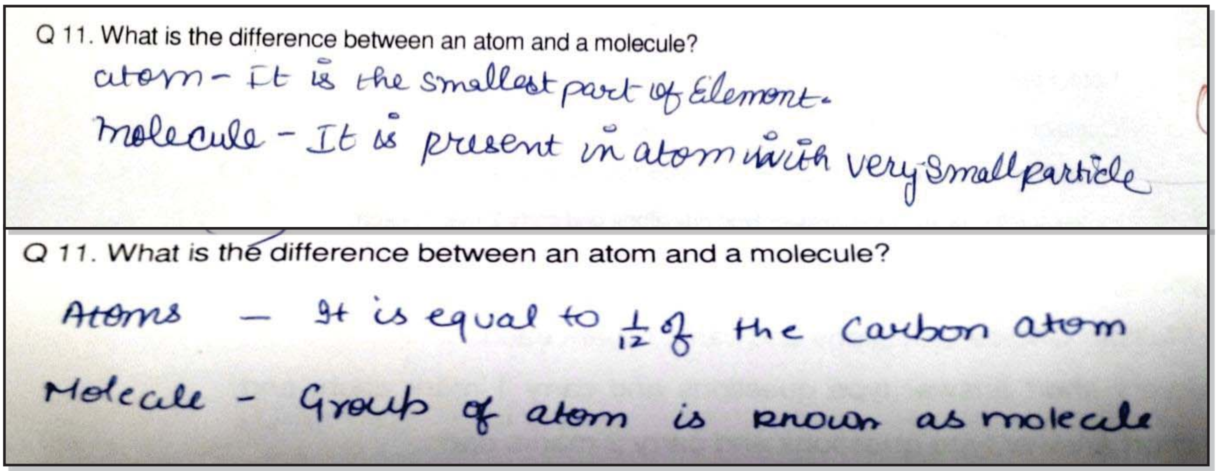


Figure 4.3 Some novice category sample answers for item 11

In item 19 of the ATS9, students were asked to explain the process of propagation of sound in the air from the school bell to their ears. The answers for question 19 were evaluated in terms of the presence of important keywords of compression, rarefaction and vibration of air molecules to carry the sound produced. For this question, 19 % of students from the intervention group and only 9 % from the comparison group were placed in the *proficient* category. For the *intermediate* and *novice* categories the proportions of students in the intervention and comparison groups were 64 % and 55 % and, 17 % and 36 % respectively. Sample answers obtained for the three categories are given in Figures 4.4, 4.5 and 4.6. The sample answer written by a student displayed in Figure 4.4, which was placed in the *proficient* category, shows an appropriate use of the valid terminology and keywords to explain the process of propagation of sound in the air.

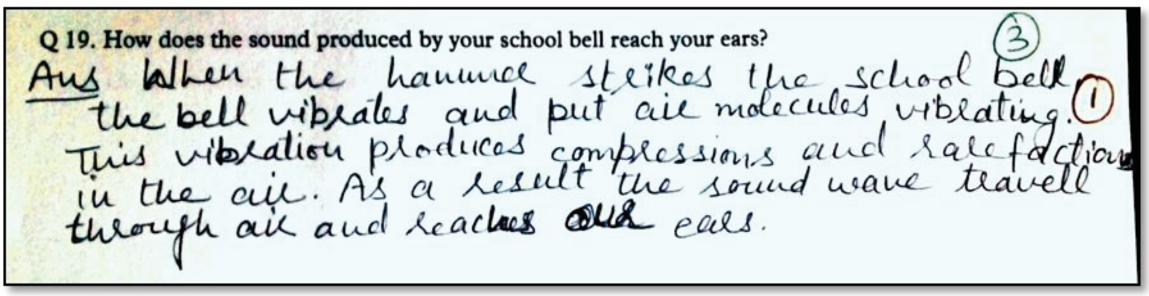
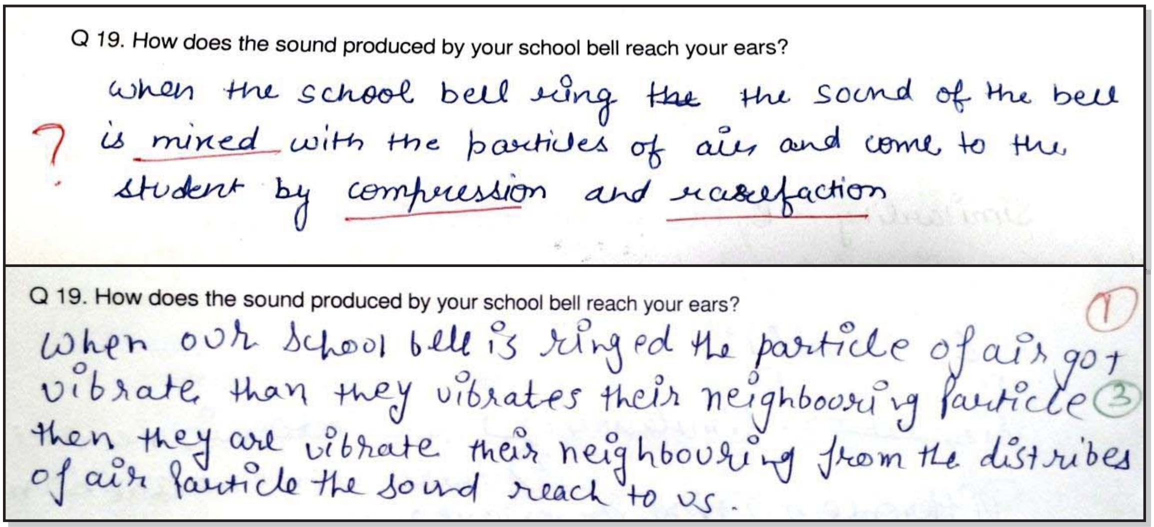


Figure 4.4 A sample answer for the *proficient* category for item 19

Some samples of the *intermediate* category answers obtained for item 19 of the ATS9 are shown in Figure 4.5. For the i*ntermediate* category responses, the majority of the participants in the intervention (64 %) and the comparison (55 %) groups appeared familiar with the concepts of rarefaction and compression of the medium (air) but could not demonstrate an explicit understanding of the process of sound propagation.


Q 19. How does the sound produced by your school bell reach your ears?

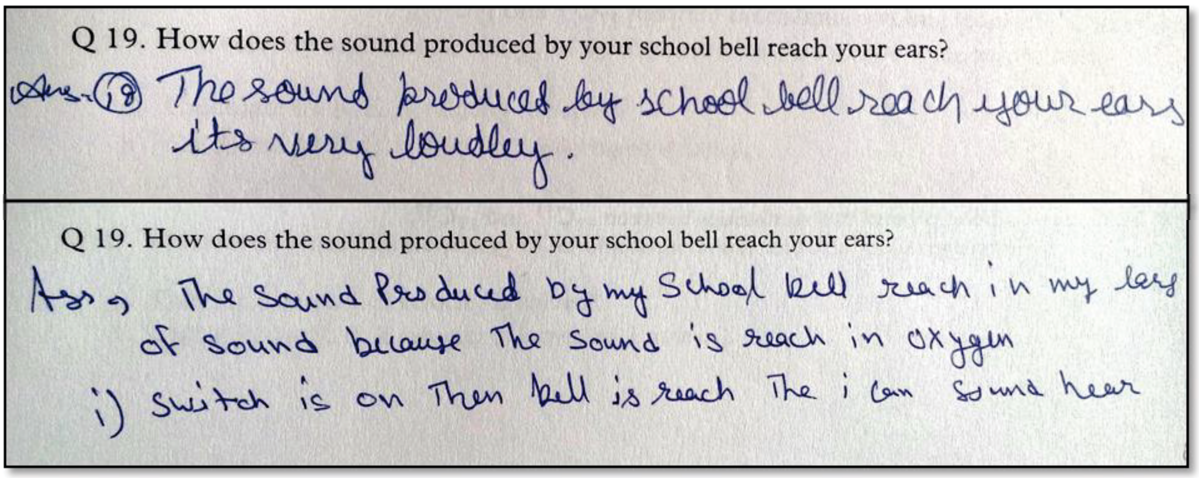
when the school bell ring the the sound of the bell is mixed with the particles of air and come to the student by compression and rarefaction

Q 19. How does the sound produced by your school bell reach your ears?

When our school bell is ringed the particle of air got vibrate than they vibrates their neighbooring particle then they are vibrate their neighbouring from the distribes of air particle the sound reach to us.

Figure 4.5 Some sample answers for the *intermediate* category for item 19

Figure 4.6 displays some answers placed in the *novice* category for question 19. These and other similar answers obtained from the intervention and comparison group students revealed a faulty and shallow level of conceptual understanding along with the presence of many misconceptions. The two answers listed in Figure 4.6 indicate the low levels of learning and conceptual understanding of students who answered this question. In the first response the student states the intensity of sound of the school bell instead of explaining the process of sound transmission. The second response indicates the possibility of a misconception that the sound is transmitted because of the presence of oxygen in the air.


Q 19. How does the sound produced by your school bell reach your ears?

Ans. (19) The sound produced by school bell reach your ears its very loudley.

Q 19. How does the sound produced by your school bell reach your ears?

Ans The sound Produced by my School bell reach in my leg of sound because The Sound is reach in oxygen
i) switch is on Then bell is reach The i can sound hear

Figure 4.6 Some sample answers for the *novice* category for item 19

4.2.2. Results for questions that assess higher-order cognitive skills

The remaining ten open ended questions out of the 23 from the ATS9 assessed the higher-order cognitive skills (HOCS) of detailed comprehension, application, analysis and synthesis of knowledge and demonstration of scientifically valid understanding. The answers for the 10 HOCS questions written by students were assigned the scores 1, 2, 3 and 4 for the *novice, intermediate, proficient* and *advanced* categories respectively. The scoring for the HOCS questions was done separately by adding the scores assigned to the answers provided by the students in the intervention and comparison groups. An independent samples *t*-test was administered on the total HOCS scores to study the difference in conceptual understanding scores between the intervention and comparison group students. Similar to the main effects of the intervention (section 4.1.3), to examine the effect of the intervention on conceptual learning, the two intervention groups A and C and the two comparison groups B and D were combined to make one each of the intervention and comparison groups. The results obtained from the independent samples *t*-test are displayed in Tables 4.11 and 4.12.

Table 4.11 shows the descriptive statistics results for the intervention and comparison groups in terms of the group samples (N), group means for conceptual understanding scores, and standard deviations from the means and the standard errors of the means.

Table 4-11 *Descriptive statistics for the independent samples t-test for HOCS*

Group statistics (Dependent variable: Conceptual learning scores for HOCS)				
Groups	N	Mean	Std. Deviation	Std. Error Mean
Intervention	111	23.86	8.49	.81
Comparison	107	19.93	8.27	.80

The results obtained from the main effects of intervention test are displayed in Table 4.12. The first two columns of Table 4.12 show the results for Levene's test, which is to check if the variances among the two groups are homogeneous (equivalent) or not. The *F* value of 0.77 and the significant value of $p = 0.38$ of this test suggest that there is no statistically significant difference between the variances of the two groups. In other words, the variances among the intervention and comparison groups are equivalent. These results indicate that the assumption of homogeneity of variances in the groups is met.

Table 4-12 *Results for the independent samples t-test for HOCS*

Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
.77	.38	3.47	216	.001	3.94	1.14

The next columns of Table 4.12 show the results for the independent samples *t*-test for the intervention and comparison groups. The interpretation of the results obtained for the main effect of the intervention test is presented as below:

> An independent-samples *t*-test was conducted to compare the conceptual learning scores for the intervention and comparison group students. There was a statistically significant difference between scores for the intervention group (*M* = 23.86, *SD* = 8.49) and the comparison group (*M* = 19.93, *SD* = 8.27; *t* (216) = 3.47, *p* = .001).

The results of the *t*-test for conceptual learning suggested that the intervention-computer-based collaborative concept mapping (CCCM)- has a positive effect on the conceptual learning of the intervention group's secondary school students. Therefore, the null hypothesis H_{o2}: *CCCM does not affect conceptual learning of Indian secondary students in science*, is partly rejected.

The percentages of responses according to the four categories of answers set out by the assessment rubric (appendix I) for the intervention and comparison groups are reported in table 4.13. A visual description of the percentages data from the Table 4.13 is presented in appendix P. A comparison of the percentages in the four categories of *advanced*, *proficient*, *intermediate* and *novice* between the intervention and comparison groups provides some information about the evidence of conceptual learning related with the HOCS items. The first column of Table 4.13 shows the corresponding question number on the ATS9. Table 4.13 describes the proportions of students placed into the four categories to provide a simple comparison between the intervention and the comparison groups. Some of these comparisons along with the sample answers provided by students are illustrated in the following paragraphs.

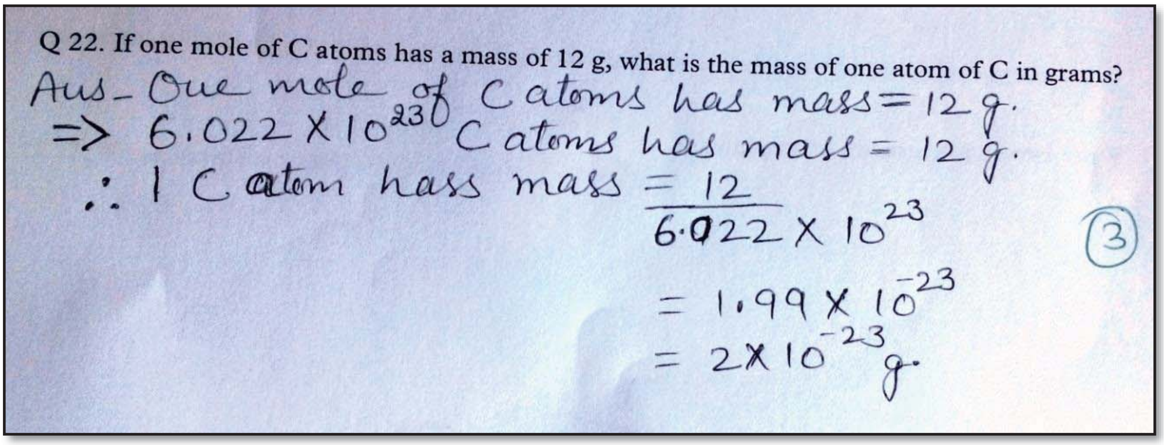
Table 4-13 *Percentages of responses for questions that assess HOCS*

Question number in ATS9	Percentage of responses							
	Advanced		Proficient		Intermediate		Novice	
	Int.* Group	Comp.** Group	Int. Group	Comp. Group	Int. Group	Comp. Group	Int. Group	Comp. Group
12	32	21	38	24	17	35	13	20
14	9	6	23	14	58	61	10	19
22	7	4	15	7	22	8	56	81
23	18	9	42	22	27	48	13	21
24	22	12	23	17	44	52	11	19
26	63	45	19	24	13	21	5	10
29	11	7	14	8	23	16	52	69
30	10	8	18	15	55	31	17	46
33	24	11	26	14	39	22	11	53
34	6	2	11	7	21	12	62	79

Notes: Int.*: Intervention, Comp.**: Comparison

The question/item number 22 of the ATS9 requires students to solve a problem based on the concept of the *Mole*. This item requires students to demonstrate a sound understanding of the Mole Concept and then apply that understanding to solve the problem by adopting and demonstrating the correct procedure to arrive at the correct answer. Although it is a simple and straight forward question, the majority of both intervention and comparison group students found it hard to answer correctly. It is interesting to see that only 7% students from the intervention group and 4% from the comparison group answered this question according to the set criteria of the *advanced* category in the assessment rubric. The proportions of students who were placed in the *proficient* and *intermediate* categories indicated larger percentages for the intervention group than that of the comparison group. The percentages obtained for the *novice* category for question 22 revealed that 56% of the intervention group and 81% of the comparison students either could not answer correctly or had misconceptions.

Some sample answers written by the intervention and comparison group students for question 22 which were placed in one of the four different assessment categories are displayed in Figures 4.7 to 4.10. An *advanced* category sample answer to item 22 is shown in Figure 4.7. This answer clearly shows the student's thinking and understanding of the Mole concept and the use of that understanding to solve the problem based on the concept. The use of valid terminology and the correct procedure to solve the problem places this answer in the *advanced* category of responses.


Q 22. If one mole of C atoms has a mass of 12 g, what is the mass of one atom of C in grams?

Ans- One mole of C atoms has mass = 12 g.

=> 6.022×10^{23} C atoms has mass = 12 g.

∴ 1 C atom hass mass $= \frac{12}{6.022 \times 10^{23}}$

$= 1.99 \times 10^{-23}$

$= 2 \times 10^{-23}$ g.

③

Figure 4.7 A sample answer for the *advanced* category for item 22

A *proficient* category sample answer to question 22 is presented in Figure 4.8. In contrast with the *advanced* category answer, this response lacks the comprehension and terminology that students are expected to use to show their thinking, although this response indicates some evidence of correct procedure to solve the problem.

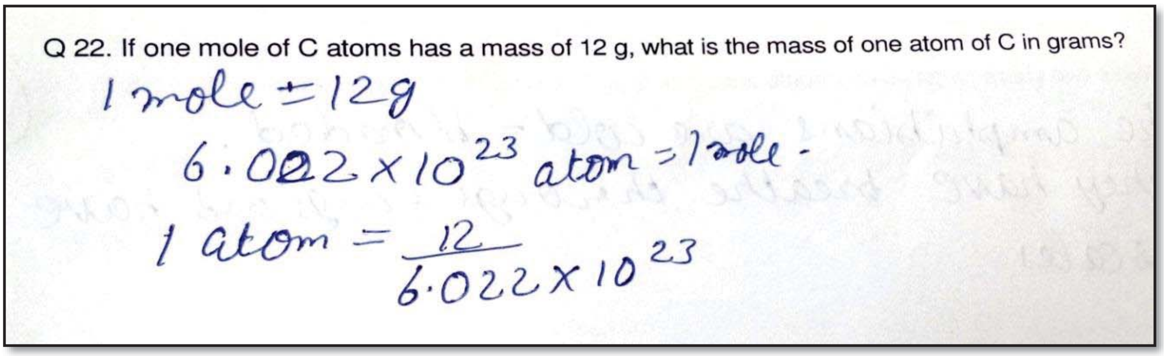


Figure 4.8 A sample answer for the *proficient* category for item 22

A sample of the *intermediate* category response for question 22 is shown in Figure 4.9. Although this response provides some evidence of understanding, it also indicates some confusion on the part of the respondent. In the first few lines the student seems clear that the mass of one mole of Carbon atoms is 12 grams and one mole of Carbon contains 6.022 x 10^{23} atoms. But, in the last few lines student's understanding of the question appears incomplete and the student calculated the number of atoms in one gram of Carbon rather than calculating the mass of one Carbon atom in grams. It appears that the student misinterpreted the question.

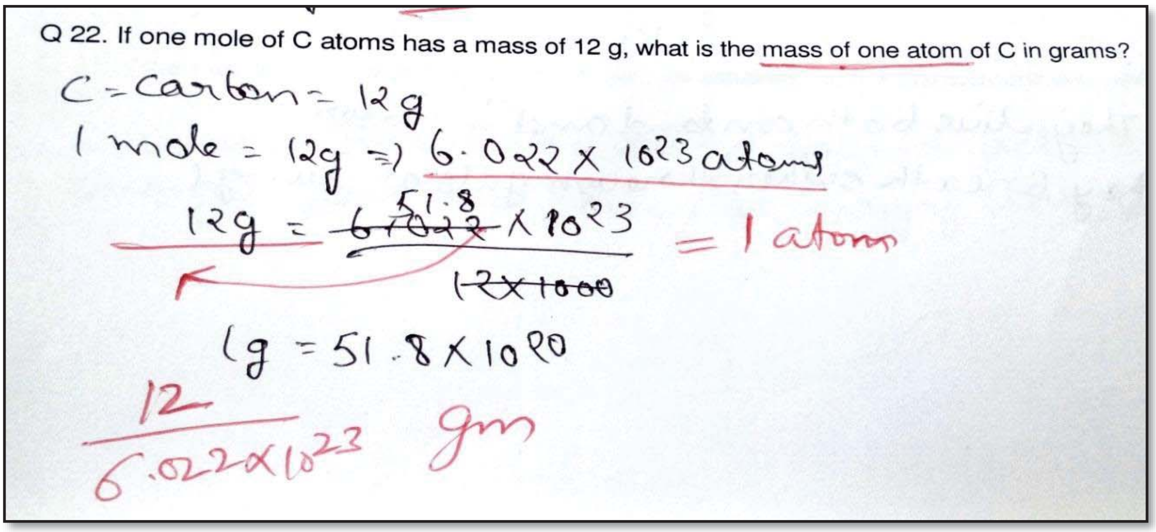


Figure 4.9 A sample answer for the *intermediate* category for item 22

A sample of the *novice* category response for question 22 is displayed in Figure 4.10. This sample response indicated faulty or no understanding of the response as well as of the question. The response indicated that the student did not possess an understanding of the Mole Concept and is writing something for the sake of writing an answer. The possibility of a misconception in the student's mind also cannot be eliminated.

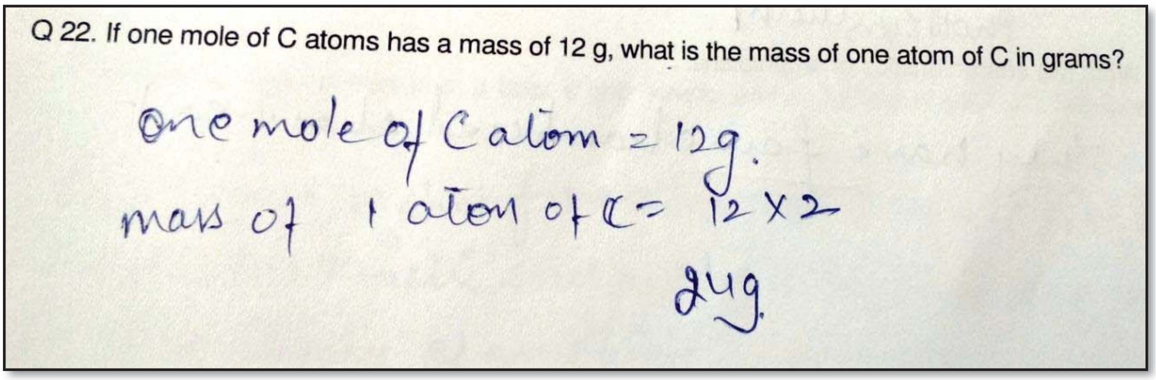


Figure 4.10 A sample answer for the *novice* category for item 22

For question 34 on the ATS9, students were examined for their procedural knowledge and conceptual understanding of the process of sound propagation. Students were asked to calculate the time after which the splash was heard after dropping a stone from the top of a tower into a well. The complexity involved in this question was to calculate the total time taken by the stone to hit the bottom and the time taken by the sound to reach at the top. Another difficulty involved in answering this question was to apply appropriate equations of motion to calculate the two times and add them to answer correctly. Table 4.13 shows that only 6 % of the intervention group students and 2 % of the comparison group students answered this question according to the set criteria of *advanced* category in the assessment rubric. The percentages obtained for the *novice* category for question 34 reveal that 62% of the intervention group and 79% of the comparison group students either could not answer correctly or indicated the presence of a wrong procedure or a misconception.

4.2.3. Individual and group conceptual learning

The nature of individual responses obtained on the ATS9 answer sheets were compared with the quality of concept maps constructed by the intervention group students in their groups. The main purpose of this comparison was to examine the individual learning and group learning of the intervention group students. These concept maps displayed important information about their thorough and partial conceptual understanding as well as misconceptions held by students in some groups within the intervention classroom. Some of the concept maps constructed by the intervention group students are displayed in Figures 4.11 to 4.14 to demonstrate clearly the level/category of conceptual learning of these students. These concept maps were analysed according to the assessment criteria given in appendix L.

The concept map shown in Figure 4.11, constructed by intervention group (N) students, was on the topic of atoms and molecules. The two groups N and T were randomly picked to present these findings. This concept map was constructed by the group after studying and discussing the concepts in their group as well as in the class. The teacher also instructed the students about how to construct a good concept map before their group discussion. This was the first concept map the students constructed in their group. The concept map shown in Figure 4.11 was placed in the intermediate category and the answers written by students of this group were analysed for conceptual learning. Three out of the five answers were placed in the novice and the remaining two were assessed as intermediate categories (appendix I). An analysis of the concept map along with the ATS9 answers shows that the students did not fully understand the concepts and this was evident in their individual as well as group work. As the concept map indicates, there is some confusion and wrong information regarding the definitions of terms atom and molecules. For example, students define molecule as the smallest unit of substance that can exist independently, which is incorrect according to the assessment criteria. The concept map also contains invalid/wrong examples, links and cross links and shows nearly poor understanding of the group. The individual answers written by these students also exhibited misconceptions and wrong information on the ATS9 answer sheets.

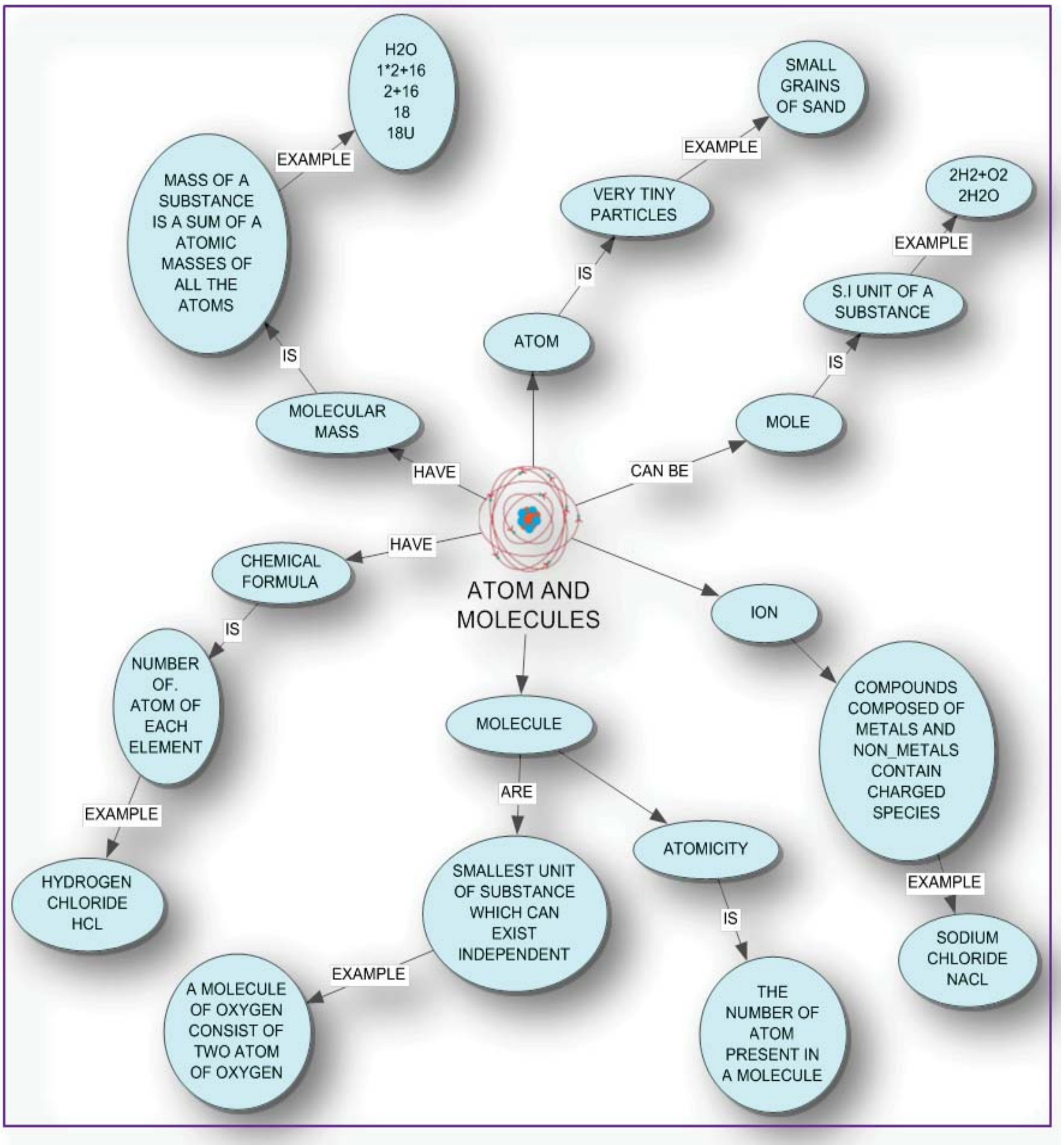


Figure 4.11 Concept map of Atoms and Molecules by group N students (*Intermediate* category)

Another concept map, constructed by group T students, shows thorough and explicit understanding of the Mole Concept and is given below in Figure 4.12. The concept map was assessed as being in the proficient category against the concept map rubric given in appendix L. Four out of five students demonstrated a thorough conceptual understanding of the concept of a mole. This conceptual understanding of the four students was evident on their ATS9 answer sheets. The students of this group have demonstrated their conceptual learning in defining the concepts, linking them correctly and giving appropriate examples in the concept map.

Another concept map constructed by group N students is displayed in Figure 4.13. This map demonstrates the conceptual learning of group N students for atomic models. The concept map was placed in the proficient category because it shows correct information and valid linkage between the concepts. For example, the concept map shows the main features of the different models of atom along with correct explanations and necessary details. Three out of the five answers by this group on the ATS9 were placed in the advanced category and two were assessed of as proficient category.

The concept map constructed by group T students for the concept of diversity in living organisms (classification) is shown in Figure 4.14. This concept map shows very clearly and nicely the classification of living things with details and examples. Although this concept map lacks the linking words, this map was assessed as being in the proficient category. All five answers by the students of the group T were placed in the proficient category according to the criteria (appendix I). Students of this group therefore demonstrated good conceptual understanding of the concept as assessed individually for related achievement test items.

Therefore, the intervention group students, generally demonstrated an association between individual and group conceptual learning. However, on other occasions some students demonstrated lower levels of conceptual learning than the group learning. There were many occasions when at least one or two individual responses by students were assessed as novice category and the concept maps constructed by the group were placed in the proficient category. These differing findings may indicate the functioning of the group and raise issues about the degree of inclusion of some students in their groups.

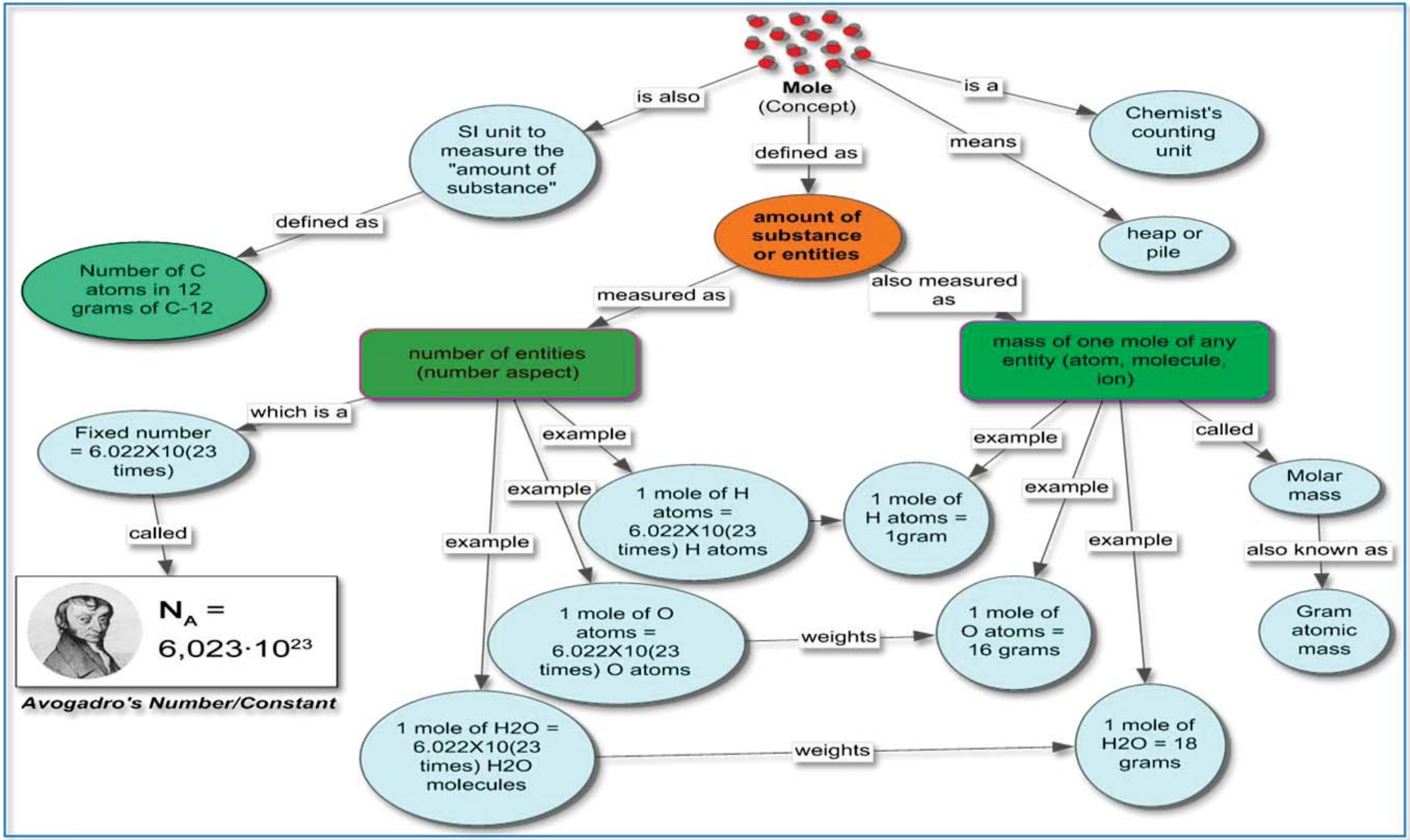


Figure 4.12 Concept map of the Mole Concept by group T students (*Proficient* category)

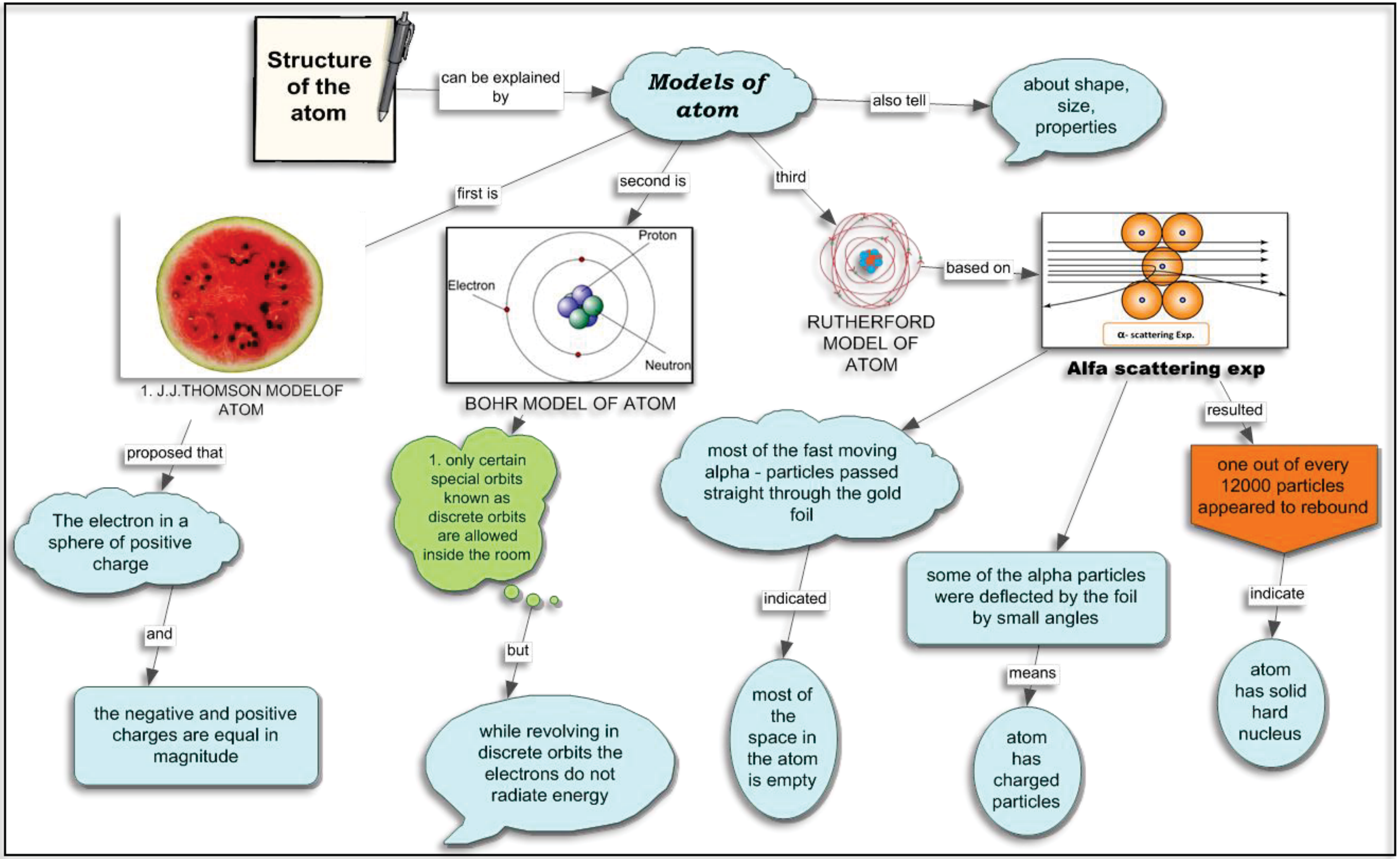


Figure 4.13 Concept map of Models of Atom by group N students (*Proficient* category)

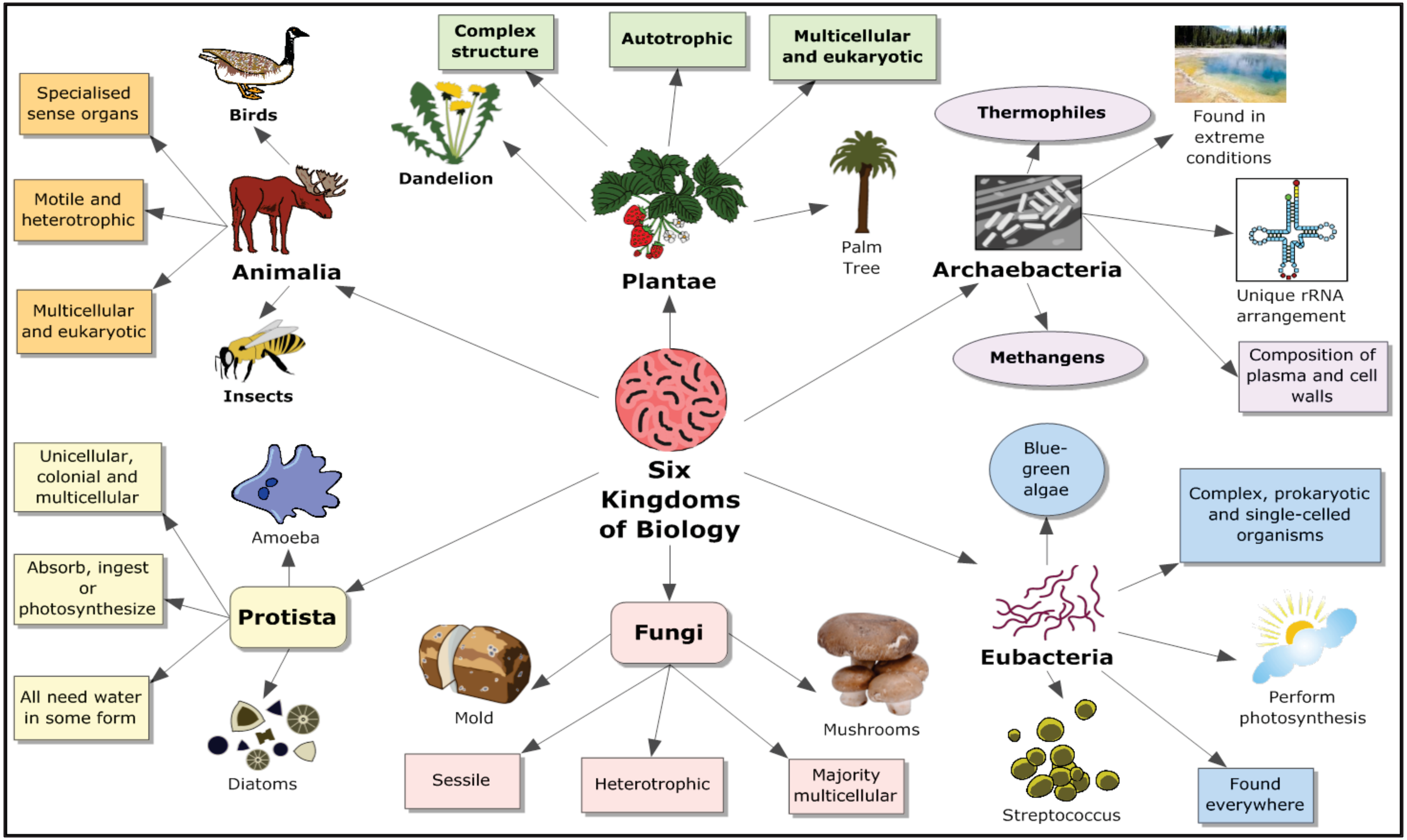


Figure 4.14 Concept map of Classification of Organisms by group T students (*Proficient* category)

4.3. CCCM and students' motivation towards science learning

One of the major objectives of this study was to investigate the effectiveness of the CCCM intervention on Indian secondary school students' motivation towards science learning. The *Students' Motivation towards Science Learning* questionnaire (SMTSL; see section 3.6.3 in chapter 3) was administered as pretests and posttests to the intervention and the comparison group students as per the *Solomon Four Group Research Design*. It is important to note that the results obtained for the effect of CCCM on motivation are limited to the data obtained from groups A and B students (school 1) only. Unlike achievement scores for the previous year's examination, students from school 2 (groups C and D) could not be checked for the equivalence or pretested for motivation levels because of the scheme of the *Solomon Four Group Research Design*. Therefore, these groups could not be included in the comparison for motivation as was the case for science achievement. This is also one of the limitations acknowledged in the limitations section 6.5 of the study.

Students' motivation towards science learning was compared based on the data obtained from the SMTSL. All students from groups A and B were pretested to assess the motivation levels before the administration of the intervention. These students were also posttested after the duration of the intervention to examine their motivation levels. To calculate the gain in motivation among students, gain scores were calculated by subtracting pretest scores from posttest scores. For example, if a student from any of the group scored a total of 125 on the pretest and 135 on the posttest, the gain score for the student is 10. Data for five students from the intervention group A, and four students from the comparison group B, who were absent in either of the tests, were excluded from the analysis because a gain score could not be calculated. The exclusion of these nine students reduced the sample size to 103 from 112 students for the statistical analysis. An independent sample t-test was carried out on the gain scores to compare the motivation towards science learning of the intervention and comparison group students. The results obtained from gain score analysis are presented in Tables 4.14 and 4.15.

Table 4.14 shows the descriptive statistics for the intervention and comparison groups A and B. The numbers of participants (N) in the intervention group and comparison group were 52 and 51 respectively. The mean levels of motivation towards science learning for the intervention group (A) students on the posttest and pretest are 127.81 (*SD* =

15.15) and 115.13 (*SD* = 13.57) respectively. The mean levels of motivation score for the comparison group (B) students for posttest and pretest are 123.41 (*SD* = 11.18) and 117.63 (*SD* = 10.64) respectively. The mean of the gain scores for the intervention group is 12.67 (SD = 14.75) and for the comparison group is 5.78 (SD = 12.83).

Table 4-14 *Descriptive statistics for the intervention and comparison groups*

Group statistics (Dependent variable: Motivation to learn science)					
Group	Test	N	Mean	Std. Deviation	Std. Error Mean
Intervention	Posttest	52	127.81	15.15	2.10
	Pretest	52	115.13	13.57	1.88
	Gain score	52	12.67	14.75	2.05
Comparison	Posttest	51	123.41	11.18	1.56
	Pretest	51	117.63	10.64	1.49
	Gain score	51	5.78	12.83	1.80

Table 4.15 shows the independent sample t-test results for the motivation gain scores. The first two columns of Table 4.15 show the results for Levene’s test which is to check if the variances among the groups are homogeneous or not. The *F* value of 0.39 and the result (*t* = 0.53 > 0.05) of this test suggest that the variances among the intervention and comparison groups are equivalent. Therefore, the assumption of homogeneity is met.

The next columns of Table 4.15 display the results for the independent samples t-test on gain scores for the intervention and comparison groups. The results obtained for the independent t-test on gain scores can be reported as:

> The difference between the intervention and comparison groups is found to be statistically significant, *t* (101) = 2.53, *p* = .013; d = 2.73. These results indicate that participants from the intervention group (*M* = 12.67, *SD* = 14.75) gained more on motivation levels than those of the comparison group students (*M* = 5.78, *SD* = 12.83).

Table 4-15 *Independent samples t-test results on SMTSL gain scores*

Dependent variable: Motivation to learn science (gain scores)						
Levene's Test for Equality of Variances		t-test for Equality of Means				
F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
.39	.53	2.53	101	.013	6.9	2.73

It is important to note the surprisingly high values of the standard deviations because of the calculation of gain scores. It appears that actual gains in motivation scores for some students from pretest to posttest were negative, which caused these high values of *SD*. However, it does not mean that the gain scores are not reliable, as argued by Sukin (2010) that in some cases, “effective instruction tends to increase the variability within a treatment group, especially when the measure used to assess performance has an ample number of score points to detect growth adequately” (p. 521). Sukin (2010) also comments that it is rare to achieve large values of variances in both the treatment and comparison groups and suggests to calculate some different measure such as Cohen’s effect size to assess the productivity of the treatment in question. Moreover, the high standard deviations simply mean that the scores are not spread around the group means but are far from the group means.

Therefore, null hypothesis H_{o3}, that *there is no difference among motivation levels of the intervention group and the comparison group students*, is rejected. Hence, the intervention- computer-based collaborative concept mapping- has a statistically significant effect on secondary school students’ motivation towards science learning. In other words, students who studied science using CCCM demonstrated higher motivation toward science learning than those who studied science using traditional methods of learning.

As described in section 3.6.3 the SMTSL questionnaire consists of six scales or components of motivation: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal and learning environment stimulation. Additional *t*-tests were carried out on the scores of these components to examine and understand the precise nature of the differences observed for the whole questionnaire. The results obtained from the independent samples *t*-tests for these six components of motivation for the pretest are displayed in Tables 4.16 and 4.17.

The descriptive statistics for the intervention and comparison group students for the six components is shown in Table 4.16 in terms of sample sizes, means, standard deviations and standard errors of the means.

Table 4-16 *Descriptive statistics for the SMTSL component scores (pretest)*

Group Statistics (Dependent variable: SMTSL component scores for pretest)					
SMTSL component	Groups	N	Mean	Std. Deviation	Std. Error Mean
Self-Efficacy	Intervention	57	19.02	4.76	.66
	Comparison	54	20.43	4.09	.57
Active Learning Strategies	Intervention	57	25.69	4.14	.57
	Comparison	54	26.18	3.92	.55
Science Learning Value	Intervention	57	16.00	3.23	.45
	Comparison	54	16.78	3.75	.53
Performance Goals	Intervention	57	7.73	3.21	.44
	Comparison	54	7.69	2.76	.38
Achievement Goals	Intervention	57	16.06	3.03	.42
	Comparison	54	16.53	3.11	.43
Learning Environment Stimulation	Intervention	57	18.52	3.52	.49
	Comparison	54	18.10	3.42	.48

The independent samples t-test result for the pretest motivation scores of the six components are presented in Table 4.17. The first column of the table indicates the names of the motivation components for which the test is carried out. The second and the third column of Table 4.17 show the results for Levene's test. The six not significant *p* (sig.) values in column three suggest that the variances in the two groups for the corresponding components are equivalent. The next five columns of Table 4.17 show the results for t-tests for the six components. The six not significant p-values (sig.: 2-tailed) in column six of Table 4.17 suggest that there is no statistically significant difference between the intervention and comparison groups for any of the six components on the SMTSL pretest.

Table 4-17 *Independent samples t-test results for the SMTSL components (pretest)*

Independent Samples Test for SMTSL pretest components							
SMTSL Component	Levene's Test for Equality of Variances		t-test for Equality of Means				
	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Self-Efficacy	1.78	.185	-1.61	109	.110	-1.41	.87
Active Learning Strategies	.24	.623	-.61	109	.544	-.48	.79
Science Learning Value	.83	.364	-1.13	109	.258	-.78	.69
Performance Goals	1.64	.203	.075	109	.940	.04	.59
Achievement Goals	.94	.335	-.77	109	.438	-.47	.61
Learning Environment Stimulation	.66	.418	.62	109	.540	.42	.68

Therefore, the motivation towards science learning for the intervention and comparison group students before the application of the intervention (for the SMTSL pre-test) is equivalent for all six components. In other words, the intervention and comparison group students do not differ in terms of motivation components' scores before the administration of the intervention.

The scores for the six motivation components from the posttest SMTSL questionnaire obtained by the intervention and comparison groups were also compared. The results obtained from the independent samples *t*-tests for these six components of motivation for the posttest are displayed in Tables 4.18 and 4.19.

Table 4-18 *Descriptive statistics for the SMTSL component scores (posttest)*

Group Statistics (Dependent variable: SMTSL component scores for posttest)					
SMTSL Component	Groups	N	Mean	Std. Deviation	Std. Error Mean
Self-Efficacy	Intervention	52	23.83	4.36	.60
	Comparison	51	21.00	4.06	.56
Active Learning Strategies	Intervention	52	29.92	5.33	.73
	Comparison	51	26.94	5.74	.80
Science Learning Value	Intervention	52	18.65	3.11	.43
	Comparison	51	16.41	4.43	.62
Performance Goals	Intervention	52	11.58	3.92	.54
	Comparison	51	10.49	2.93	.41
Achievement Goals	Intervention	52	18.12	3.67	.51
	Comparison	51	18.55	3.02	.42
Learning Environment Stimulation	Intervention	52	22.10	4.36	.60
	Comparison	51	19.76	4.16	.58

The descriptive statistics for the intervention and comparison group students for the six motivation components is shown in Table 4.18 in terms of sample sizes, means, standard deviations and standard errors of the means. The independent samples t-test result for the posttest motivation scores of the six components are presented in Table

4.19. The first column of the table indicates the names of the motivation components for which the test is carried out. The second and the third column of Table 4.19 show the results for Levene's test. The four not significant *p* (sig.) values in column three suggest that the variances in the two groups for the corresponding four components: self-efficacy, active learning strategies, achievement goals and learning environment stimulation, are equivalent. This means that the assumption of homogeneity of variances between the scores for these four components is met.

Table 4-19 *Independent samples t-test results for the SMTSL components (posttest)*

Independent Samples Test for SMTSL posttest components							
	Levene's Test for Equality of Variances		t-test for Equality of Means				
SMTSL Component	F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference
Self-Efficacy	.77	.38	3.40	101	.001	2.87	.83
Active Learning Strategies	1.06	.31	2.73	101	.007	2.98	1.09
Science Learning Value	9.94	.002	2.96	89.51	.004	2.24	.75
Performance Goals	9.8	.002	1.59	94.34	.115	1.08	.68
Achievement Goals	3.34	.071	-.65	101	.515	-.43	.66
Learning Environment Stimulation	.02	.996	2.77	101	.007	2.33	.84

The two significant *p* values of 0.002 each for the two components: science learning value and performance goals indicate a violation of the assumption of homogeneity of variances in the scores. Therefore, the values for these two motivation components were adjusted according to the rule of considering the *equal variances not assumed* values from the SPSS output (It is important to notice the transformed degrees of freedom: 89.51 and 94.34 for these two components in the fifth column of Table 4.19).

The next five columns of Table 4.19 show the results for t-tests for the six components. The four significant p-values (sig.: 2-tailed) in column six of Table 4.17 suggest that there is a statistically significant difference between the intervention and comparison groups for the four components of self-efficacy, active learning strategies, science learning value and learning environment stimulation. The difference for the remaining two components of performance and achievement goals is found to be statistically not significant. However, as calculated and reported in the earlier part of this section, the overall difference between the motivation towards science learning of the intervention and comparison group students is found to be statistically significant.

Therefore, the motivation towards science learning (based on these six components results, Table 4.16 and 4.17) for the intervention and comparison group students before the application of intervention (for the SMTSL pretest) is equivalent. In contrast, the motivation towards science learning after the application of the CCCM intervention (posttest results, Table 4.18 and 4.19) differs for four components of the SMTSL and does not differ for two components. These results offer a more specific explanation of the difference observed for the whole SMTSL questionnaire. However, the four statistically significant results for the four motivation components confirmed the rejection of the null hypothesis H_{o3}: *there is no difference between motivation levels of the intervention group and the comparison group students*. The remaining two not statistically significant results for achievement and performance goals did not affect the overall motivation of the intervention versus comparison group students and did not contribute to the rejection of the null hypothesis H_{o3}.

4.4. Science Teachers' Interview Results

One of the objectives of this research (section 1.5) was to explore the perceptions and experiences of the participant teachers and students about the use of CCCM in their classrooms. As discussed in section 3.6.4 of chapter 3, the two science teachers were interviewed to explore their perceptions and experiences of using computer-based collaborative concept mapping (CCCM) in their classrooms. The interviews followed a semi structured format (appendix M). The key themes which emerged from teacher interview transcripts were organised according to research questions 3 and 4 (refer to section 2.9) as below:

1. Teachers' views of CCCM use in science teaching and learning
2. CCCM versus other methods of science teaching and learning
3. CCCM use and conceptual learning
4. Effectiveness of CCCM in addressing misconceptions among students
5. CCCM and the classroom learning environment
6. Role of the teacher in classroom
7. Relationships (teacher-student and student-student)
8. CCCM and change in teacher practice
9. Overall experience of using CCCM in science learning
10. Factors that support the use of CCCM in science teaching and learning
11. Barriers to the use of CCCM in science classrooms

These eleven themes broadly cover the CCCM use, support for and barriers to the CCCM use in science classrooms. Themes 1 to 9 are related to the research question 3, while themes 10 and 11 are related to research question 4 of the study. The findings of these themes are presented in the next sections to present science teachers' perceptions and experiences of the CCCM use in science teaching and learning. Most of the findings are presented with relevant comments (direct quotations) from the participants' interview transcripts and a brief description is presented to summarize the interview findings. The direct quotations from participants have been presented in *italics* to differentiate them from the quotations from the literature.

4.4.1. Teachers' views of CCCM use in science teaching and learning

The two participating science teachers were asked to talk about their perceptions and experiences of the CCCM use in their classrooms. Both teachers revealed positive attitudes towards the use of the intervention and reported that the teaching experiment had been a success. Both teachers reported that CCCM as a method of teaching and learning had been very effective and they perceived that it has potential to enhance secondary school students' conceptual learning in science. Both of the teachers believed that the CCCM had been a good help to create interest and to engage students to enhance their science learning and motivation.

When asked about the uses of CCCM in science teaching and learning, both teachers indicated that the intervention could also be used as a method of assessment in addition to its use as a method of teaching and learning (although in many countries assessment is seen as an integral part of teaching and learning, in the Indian context it is still considered as a separate entity). For example, the science teacher Jai mentioned that CCCM could help students in revising of the content and could be used as a teaching aid in the classroom. Jai stated:

> *The concept mapping software is a very effective tool and it can lead to better conceptual learning. It can also be used as a teaching aid [Res: Hmm..hun[14]], and this is also good for the revision for the students and it can also be used for…, I think it can also be used for the formative assessment of the students (Jai-Tr1Sch1Int).*

The other teacher, Lata, also reported similar experiences and mentioned that she felt the CCCM had made her teaching more effective and that it could play an important role in enhancing conceptual learning in science. She also mentioned other uses of the intervention later in the interview and confirmed that it can be used as an assessment strategy. Lata commented:

> *This is a very effective method for the formative assessment of the science concepts and it can reveal students' levels of conceptual understanding. I would like to use it in my other classes and encourage other teachers to use it in their classes [Res: OK]. I have really enjoyed the teaching process using this method and it has made my teaching more effective and easy (Lata-Tr2Sch2Int).*

In addition to the use of CCCM as a teaching, learning and assessment strategy, Lata pointed out the use of CCCM as a tool to assess students' prior knowledge and stated:

> *Sometime concept mapping can reveal students' previous knowledge. When I ask my students to prepare a concept map before teaching any topic and that way I directly come to know what students know and do not know before starting any topic or concept (Lata-Tr2Sch2Int).*

Both teachers confirmed that CCCM was a very effective method for teaching and learning science and pointed out some benefits to their teaching practices. Jai identified

[14] The expression *[Hmm…hun]* is used in the interview transcripts to indicate that the listener is expressing agreement with the speaker by making this sound along with nodding

enhancement of student interaction in the class and groups, participation in the class, and increased collaboration, self-confidence, interest and engagement in science. Lata pointed out that the CCCM use had improved relationships among students as well as between the teacher and students. Neither of the science teachers expressed any negative attitudes towards the use of CCCM, whereas both teachers expressed the need and importance to implement CCCM use in other classrooms of their schools. Some other views about the CCCM use are presented in following sections.

4.4.2. CCCM versus other methods of teaching

The science teachers were asked to identify the differences between the use of CCCM and other methods or strategies of teaching and compare them based on their experiences. Both teachers perceived the use of CCCM was valuable and effective. Jai pointed out that CCCM use in his class enhanced students' focus on learning and the task at hand. Jai also reported CCCM use as promoting more active and interactive learning in comparison to the traditional methods of teaching and learning. Both of the teachers stated that they had been using collaborative learning strategies in one form or another in their classrooms, to some extent, before the introduction of CCCM. They elaborated on the differences between and advantages of using CCCM over other teaching methods. Jai mentioned that he had been using project-based learning and reciprocal teaching in his class, in which he used to assign projects to a group of 5-6 students and students had to present the project findings in class. However, Jai admitted that it was not that formal and organised as was the case of CCCM. When asked how Jai perceived group learning, he stated:

> *Learning in small groups is very effective, because the students, with the…, in small groups, students learn better. Because it involve peer learning [Res: Hmm..hun]. And the, the students can clarify the concepts in better way in small groups. And uh.., it leads. It enhances the discussion, and uh.., there is lesser burden on students (Jai-Tr1Sch1Int).*

Later in the interview when asked to differentiate the intervention from other methods, Jai mentioned some distinctive features of using CCCM. He pointed out the nature of the interaction and stated CCCM was "more interactive" during teaching-learning. Jai also reported some changes in the classroom setting instigated by CCCM use, for example, students' personal accountability and peer-support in groups, more discussion, constructive feedback, following up of the group norms and the ground rules, focus on the learning, taking responsibility and being responsible for learning of every group member and accountability towards the group success-all of which he had not encountered using other methods.

Furthermore, Jai highlighted other effective aspects of CCCM while comparing it with other methods. Jai stated that the use of group learning and ICT in the CCCM could affect students' conceptual learning. Jai also mentioned that he started using the CCCM intervention in his other classes. Jai stated:

> *Because we use learning in small groups, and we also use computer in this technique, so it is a, it is effective in two ways- learning in small groups is always interesting as it leads to better clarification of the concepts and all the students are excited and motivated because we make use of the technology. I have started using this technique for all my classes. So I have found this technique more effective than any other method I used previously (Jai-Tr1Sch1Int).*

On the other hand, Lata perceived the use of CCCM as a complete change of her teaching practice. Lata acknowledged that the new method of teaching and learning science was better than other earlier methods she had used. Compared to Jai, who had used group learning to a considerable extent in his class, Lata reported that she had used it only to a small extent in her class. She expressed very positive views about CCCM in her class and mentioned that this strategy has helped her students learn better in comparison with other methods. Lata also reported that students preferred CCCM over the other methods of teaching and learning. Lata said:

> *My students used the co-operative learning strategies, but in a different way. Students used project-based learning in small groups. To some extent, they were familiar about learning in a group. But this was a very different experience for them, as their roles were changed in this technique [Res: OK]. Students have shown more interest and did a good job of learning science in small groups. They also preferred using this technique more often in the class (Lata-Tr2Sch2Int).*

When asked to explain the differences, Lata pointed to the change in the interactions and relationships among students, students taking more interest, showing more engagement with the content and doing better learning in her class. Lata also preferred CCCM over other methods of teaching science that she had used earlier in her teaching career.

4.4.3. CCCM and conceptual learning

The two participant teachers were asked about the role that CCCM could play in students' conceptual learning. Both teachers asserted that CCCM could enhance conceptual learning and explained the process from their different point of views. When asked to elaborate how it enhances conceptual learning, Jai mentioned that to construct a good concept map students need thorough knowledge of the topic; the main and the sub-concepts and their relationships in terms of the linking words. Jai pointed out that while creating the concept maps, when students try to make sense of the relationships, it enhances their conceptual learning. Jai stated that:

> *Yes, the concept mapping is very effective in promoting conceptual learning. It involves… to make, a concept map, students should have a thorough knowledge of their topic, of the subject matter. [Res: OK]. And also, it also involves the relationships of various concepts [Res: OK]. Students need to have the knowledge of correct relationships between various concepts [Res: Hmm..hun]. So, it leads to conceptual learning (Jai-Tr1Sch1Int).*

When asked about the relationships between concepts and conceptual learning, Jai mentioned that if a student can show the correct relationships between the concepts that means the student has better conceptual learning. Later in the interview Jai reflected on the process of conceptual learning through group concept mapping in terms of enhanced interest, interaction, participation and achievement of the common group goals. Jai reported that because of the group participation most of the students took an interest in learning the concepts and contributed towards the achievement of the group goals (of understanding science), which could lead to conceptual learning. Jai added:

> *Like, it involves participation of all the students in the group [Res: OK]. And all the, those students who initially take lesser interest, as the group discussion advances, all the students start taking interest and all the*

students start participating [Res: OK]. It gives a sense of achievement when they all contribute [Res: OK]. And it also leads to excitement when they all are working toward the common goal (Res: OK). In a group, there is lesser burden on each student, and with the help of concept map it leads to better conceptual learning (Jai-Tr1Sch1Int).

When asked to give an example of a time when students learned a concept better using the CCCM in the class, Jai reported:

There have been many incidents when students learned better in a group and clarify their concepts. In one of the biology chapters, named Classification ..., oh no ..., 'Diversity in Living organisms', students learned well from each other than they would have learned in the class or individually. Small groups provided them a platform to add, agree, disagree, argue or support other member's point of view. They were making sense of the information and doing well, as I was just observing and occasionally supporting them to refine their concepts. As a result, all the students learned the unit conceptually and I could see my students going with clear understanding from my science class (Jai-Tr1Sch1Int).

The second teacher, Lata reported similar perceptions and experiences about the role of CCCM in enhancing conceptual learning of students in her class. She stressed the importance of using CCCM in her other classes and throughout the school. When she was asked whether or not CCCM could enhance conceptual learning of students and if so, how it could do so, Lata affirmed that CCCM could certainly enhance conceptual learning by helping students in understanding the relationships between different concepts and making students' thinking visible to themselves and the teacher. Lata specified:

I would say- absolutely yes. Concept mapping is very effective in enhancing conceptual learning of science concepts. In concept mapping, students have to understand the concepts and their relationships with other concepts and then link them appropriately [Res: OK] and their conceptual understanding can be seen through ..., through these maps. When students cannot prepare a good concept map or make it of poor quality, a teacher can directly know *that the student did not understand the concepts and can work with the students to correct and make them understand (Lata-Tr2Sch2Int).*

Lata also mentioned an incident when students did not learn the topic *Mole Concept* well after she had taught it in the class but they learned it better using CCCM later. She stated:

I recall a time when my students were learning the 'Mole Concept' in their class. Even after my demonstration and explanation of the concept, many students did not understand the Mole Concept. It was evident from the …, the concept maps they were making. Only two groups of students could make efficient and clear maps of the Mole Concept. Then I had to teach the concept again and asked those well performing students to discuss the concept in the class. They came up with a very good understanding and explanation of the Mole Concept and supported other students to understand well (Lata-Tr2Sch2Int).

When asked how she came to know that students did not understand the Mole Concept well, Lata stated that she could observe students struggling to negotiate the meanings and showing wrong conceptions while constructing concept maps. She remarked:

I could notice when students were finding it difficult to prepare concept maps and were not progressing even after three days on the same map. I waited for three days and sensed that I needed to teach the concept again. Students did well after that on the Mole Concept and prepared some good concept maps (Lata-Tr2Sch2Int).

Therefore, both science teachers confirmed the important role played by CCCM to enhance students' conceptual learning in secondary science. The teachers reported that by observing students while using concept mapping or making incorrect concept maps, they could notice whether or not conceptual learning was happening. They also suggested using CCCM in other subjects and classrooms for better conceptual learning.

4.4.4. Effectiveness of CCCM in addressing misconceptions among students

Teachers were asked to talk about the use and effectiveness of CCCM to identify and correct misconceptions held by students in their classes. Both teachers perceived and expressed an affirmative role of the intervention to reveal and to some extent correct students' misconceptions in science learning. Lata reported what she had been observing over the few years stating "*over the last few years, I observed that many of my students were coming to my science classes with many misconceptions in their head*". She mentioned that she tried to find solutions for the misconceptions. She reported that she searched some literature on how to find and correct misconceptions but did not succeed. Lata mentioned that in spite of her efforts to correct the prevalent misconceptions, many of her students were still showing misconceptions in many topics. When asked to speak on the effectiveness of CCCM in clarifying misconceptions, Lata stated that most of the time students' talk (discussion) can indicate their wrong understanding. She also mentioned that concept mapping can reveal misconceptions by making students thinking visible to teachers. The wrong concept maps created by students in terms of wrong concepts and connections can show the presence of misconceptions. Lata reported her experience stating:

> *CCCM makes the knowledge of a student visible by clearly showing relationships between various concepts (Res: OK), that shows the conceptual learning. When students develop concept maps, they will ..., make either correct or faulty concept maps. A teacher then can work on these and clarify and correct them. So, I think it plays a good role to clarify misconceptions among students (Lata-Tr2Sch2Int).*

Jai also confirmed an important role for CCCM in identifying and correcting students' misconceptions in science. Further, in the interview, about the effectiveness of CCCM for clarification of misconceptions, he stated that the use of right or wrong relationships among concepts could indicate a misconception. Jai commented:

> *Then, the uh.., it makes use of the uh.., relationship between the various concepts (Res: OK), that leads to conceptual learning, better conceptual learning and it clarifies the..., it addresses the misconceptions of the students in a topic and therefore it leads to better conceptual learning (Jai-Tr1Sch1Int).*

When asked whether or not he would recommend CCCM use to correct misconceptions he mentioned "*Yes, definitely, it* [CCCM] *is a very effective tool to address* *misconceptions in science learning*". Therefore, both science teachers indicated the potential of CCCM in revealing and correcting students' misconceptions in science and thus pointed out CCCM use as an assessment tool to diagnose misconceptions.

4.4.5. CCCM and the classroom learning environment

The teachers were asked to talk about the ways the use of CCCM affected the classroom environments. Both science teachers confirmed that the intervention-based learning approach provided an encouraging and interactive environment which promoted conceptual and meaningful learning. When asked if Jai noticed any change in the classroom learning environment, he mentioned some transformed features of his classroom environment, such as interactions among students and teacher, more questioning, enhanced students' confidence and engagement, and improved thinking skills. Jai articulated:

> *Yes, of course uh.., I noticed many changes in the class. First, it is more interactive, in the sense students get lot of opportunities to interact and learn. Then, students feel very comfortable to discuss and ask anything to me and question more in the classroom. Students appeared more confident, engaged and active in the learning process. They [Students] are engaged most of the time and take interest in learning new concepts which was not there in the class, before. And most important, I have seen a positive change in students' communication and thinking skills and there is less competition and more collaboration than before (Jai-Tr1Sch1Int).*

Lata also mentioned some aspects of the classroom learning environment, for example improved communication, relationships, and focus on learning, and enhanced interest and attitudes of students in the class due to CCCM use. Some specific and common aspects of the classroom environment the two science teachers mentioned were: change in teachers' roles, teacher-student and student-student relationships in the classrooms and change in teachers' beliefs and practices. These are presented in next few sub-sections.

4.4.5.1. Role of the teacher during CCCM

As part of the interviews, teachers were asked to reflect on and talk about the way they perceived their role as a teacher in relation to the classroom environments. Jai described how his role had changed to that of a learner, coach and a facilitator from that of a lecturer and reservoir of knowledge. Jai stated:

> *Well, I knew about child-centred learning and the role of a teacher to make it happen in the class. I believed and still believe that a teacher has a prominent role to play in the classroom. Other than summarising the science topics in a brief lecture, I was there in the classroom to create conditions to enhance the interactions and discussions. I was there to facilitate the discussion in the process of learning. I used to be more like a knowledge authority and imparting agency before using CCCM (Jai-Tr1Sch1Int).*

At a later stage of the interview, Jai revealed that he himself had learned a lot from the use of CCCM in his classroom. Jai articulated the view that a teacher still has an important role to play in the classroom and stated that he cannot solely be dependent on the computer and students' groups. At one point in the interview Jai mentioned that he "*was there to guide and facilitate the discussion and support my students to learn conceptually*". Lata also pointed to a change in her role as a teacher. She mentioned that she had "*provided complete freedom to students in my classroom and encouraged them to learn from the intervention as much as they could*". She described her role as a facilitator and a guide to organise and monitor discussions and to motivate students to learn conceptually. She stated:

> *I have tried to be a guide, guiding students in their learning. Part of my job was ensuring that students were engaged and working together and supporting each other in their learning. Another aspect of my role was to act like a coach to motivate students towards setting of learning goals, acting towards achievement of those goals and providing feedback whenever and wherever needed (Lata-Tr2Sch2Int).*

Lata also mentioned her supplementary role of a motivator and a coach in addition to her earlier role of a class teacher. An additional characteristic Lata pointed out was that of providing detailed feedback, which according to her was very important to the promotion of conceptual learning in her classrooms. Therefore, both teachers had experienced a change in their roles, and made this explicit at different parts of the interviews.

4.4.5.2. Relationships in the classrooms during CCCM

The science teachers were asked how they perceived or experienced the teacher-student and student-student relationships in their classroom as a result of CCCM use. Both science teachers acknowledged an improvement in both types of relationships as a result of CCCM use and mentioned some changes. Jai pointed to the development of confidence and trust from students' as well as teachers' perspectives. He mentioned that, "*they* [students] *felt more comfortable and confident in approaching me* [the teacher] *and I have tried to be very friendly in dealing with problems faced by students*". Jai also referred to the collaborative and encouraging relationships among students saying, "*Students motivated each other and intelligent students helped and showed responsibility to help weak students to learn and progress*". Jai perceived that the nature of teacher-student and student-student relationships in his classroom was primarily very friendly.

Lata highlighted the respectful nature of the relationship between the teacher and students. She mentioned that she had experienced an enhancement in respect and trust in the eyes of her students as a result of giving more autonomy and freedom to them. During the interview she mentioned that she could see students being friendlier and interacting well with her, as well as being more comfortable in asking questions and asking for clarifications. She said:

> *Students took responsibility of their learning and encouraged each other to become more confident and competent. I have always believed in my students' abilities and my own strengths to work together to achieve a goal. My students had shown a great deal of co-operation with me to learn science and they in turn believed in me as their well-wisher or guardian (Lata-Tr2Sch2Int).*

Neither of the teachers mentioned any negative comments about the relationships in their classrooms and both teachers generally agreed that the use of the intervention improved the teacher-student and student-student relationships in their classes.

4.4.5.3. Teacher change as a result of CCCM use

Both teachers acknowledged changes in their beliefs and practices as a result of using CCCM in their classrooms. Although Jai had practiced collaborative learning previously he believed that his practices had improved and his beliefs had changed. Jai stated that the intervention had enriched and confirmed his beliefs about the impact of collaborative learning in promoting conceptual learning in science. He pointed out an addition of "*two important things*" to his knowledge and practice with which he was not familiar before implementing the CCCM intervention in his class. The first was that he started "*focussing on learning as a process and not as a product*". Second, Jai stated that he became familiar "*with the concepts of assessment for learning and providing appropriate and timely feedback*".

Jai described how the use of the intervention in his class had added many things to his beliefs about student-centred pedagogy such as additional role of the teacher as a supporter, motivator and creator of conditions for learning and assessment, providing freedom, autonomy and feedback, and sharing responsibility in the class. Jai admitted this change in his practices in terms of transferring agency, responsibility and freedom to students and improved his attitude towards students.

Lata also reported a substantial change in her practices and beliefs. As she mentioned earlier in the interview, she had previously used group work in her class but not often. She also reported that the use of the CCCM intervention has added some essential things like knowledge of different learning theories, types of collaborative learning activities, giving freedom to students and reflecting on her teaching practices. She stated:

> *As far as my beliefs are concerned, I have felt that the practice of CCCM has added some important things to my knowledge and practice. Now, I am aware of the major theories of learning and I am a firm believer of the constructivist theory and collaborative learning and their impacts on students learning. I have experienced a change in my practice about providing students with the responsibility of their learning and believing in their strengths and weaknesses. This has helped me to think about and reflect on my own teaching practice (Lata-Tr2Sch2Int).*

Therefore, both of the participant teachers perceived and experienced the use of CCCM as beneficial for their teaching practices. During the interviews, both of the teachers reported positive experiences and benefits of CCCM use in their classrooms.

4.4.6. Overall experience of using CCCM in science learning

At the end of the interview, both teachers were requested to reflect on their overall experience of the CCCM use in their classrooms. Both science teachers appeared satisfied with the CCCM use and expressed their intentions to implement CCCM in their other classes. Jai reported that he will request for the school principal to arrange for the software and will conduct a workshop to train his colleagues. Jai stated:

> *I have started using it, as I have said earlier, I have started using it for all my classes [Res: OK], and I would, wherever and whenever I get a chance, I will also convey the same thing to all my colleagues, to all the other subject teachers, so that they can also make use of it and get benefits from this technique (Jai-Tr1Sch1Int).*

When asked whether or not CCCM could play an important role in designing a constructivist learning environment, Jai affirmed that it certainly could. Jai highlighted the important aspects of group work and collaborative functioning. He perceived that the improved interest, focus on learning and understanding, peer-support and feedback could play key roles to design constructivist learning environments. Jai said:

> *I think, yes. This can play a very good role to enhance the learning and student achievement as students work in the group and the main aim is to enhance their [students'] understanding of the concept. There is a good collaboration in most of the groups and students help weak students to improve their learning. Students take interest, enjoy the learning process and take ownership of their learning. They can assess their learning in the group. Their self-esteem is enhanced and they are engaged in the group activity because they want to improve themselves and learn many skills (Jai-Tr1Sch1Int).*

Lata also perceived and confirmed an important role played by the CCCM intervention in supporting constructivist learning environments in secondary science classrooms. At the end of the interview she added that "*learning science using computer-based* *collaborative concept mapping is very effective as it leads to better conceptual learning because students show interest and are engaged with the subject matter or topics for a long time until they master them*". Lata also reported that she would recommend and make arrangements to implement CCCM use in her school. She stated:

> *Yes, for sure. I would like to tell the benefits of concept mapping and group learning and suggest other teachers in the school to implement the concept mapping in their classes. I will try to encourage other teachers and the school principal to encourage and make arrangements for the use of the computer-based collaborative concept mapping in our school (Lata-Tr2Sch2Int).*

Therefore, both science teachers predominantly expressed positive attitudes towards CCCM use and recommended that it should be used to enhance conceptual learning by finding and addressing misconceptions in secondary science. Neither indicated negative attitudes or perceptions towards CCCM use as a teaching and learning strategy. CCCM use as an assessment strategy was also made explicit. Both teachers recommended using CCCM not only in all of their classes but also in other classrooms in their schools.

4.4.7. Factors that support CCCM use in science teaching and learning

The final *Research Question 4* of this study focussed on identifying the supports for and barriers to CCCM use in the Indian secondary science classrooms. The participating teachers were asked to talk about the enablers and difficulties of using CCCM in their classrooms and other possible factors which could promote or hinder the CCCM use. Both science teachers pointed out many enablers and barriers related to the teacher, the students and the school. These factors identified by teachers are reported in the following sub-sections.

4.4.7.1. Enablers related to the science teacher

Both science teachers perceived the teacher's expertise, knowledge and awareness of different teaching strategies as an important enabler in the use of CCCM to promote student learning. Lata gave importance to the expertise of science teachers to use the software whereas Jai focussed on teacher awareness and exposure to different teaching strategies including CCCM. Jai pointed out that "*a science teacher should use this* *technique in the classroom in an appropriate way*". When asked to elaborate the meaning of appropriateness, he commented:

> *I mean the teacher should motivate the student in an appropriate manner so that all the students take interest in it (Res: OK), the teacher should have good knowledge of different theories of learning and motivation behind any technique (Jai-Tr1Sch1Int).*

For Jai, the pace of the lesson and the patience of the teacher were other important factors that could support CCCM use in his class. He mentioned that the change in the teaching practice should be a gradual and not a sudden process. Jai also stated that a teacher should have a good knowledge of students: their beliefs, prior knowledge and misconceptions before using CCCM in their classes. Teachers' knowledge of the subject matter and their training in using the software was also an additional factor identified that could promote CCCM use in science class.

Lata mentioned the teachers' expertise in using CCCM in two ways: training in using concept mapping as well as training in using the concept mapping software. She felt that unless a teacher has the knowledge of implementing both of these, the CCCM cannot work well. Lata also stressed on the need to provide sufficient time to students so that they could master the functionalities of the technique. She stated:

> *Then a teacher should provide sufficient time to students to get familiar about the technique and the concept mapping software. I asked my students to practice making concept maps on chart papers and then I told them about the software and explained the functions in the software (Lata-Tr2Sch2Int).*

Some other factors highlighted by Lata were pacing of the lesson, providing constant encouragement and feedback, and consideration of students' knowledge and beliefs before using CCCM in science classrooms, which could promote the CCCM use.

4.4.7.2. Enablers related to students

Students' attitudes towards, as well as beliefs and perceptions about, CCCM were found to support its use in science classrooms. Lata emphasised students' understanding of science concepts while Jai pointed out affective factors like student interest and motivation as important enablers to effective CCCM use. For Jai, enablers related to students included students knowing the importance of using CCCM and being motivated to use it in their learning, whereas Lata indicated students' sound understanding of science concepts as a prerequisite condition for effective CCCM use to promote students' learning and motivation. Students' familiarity with and mastery of the process of concept mapping was another factor outlined by both teachers which could promote the CCCM use.

4.4.7.3. Enablers related to the school

Infrastructure availability in schools was identified as an enabler considerably impacting CCCM use in the schools. Both teachers pointed to the availability of sufficient computers and software in their schools. The attitude of the school head and support from an ICT instructor were also mentioned as major factors that could support the smooth use of CCCM in secondary classrooms. Availability of the internet connection was another important factor that was identified as having the potential to promote the CCCM use in the science classrooms. Although, internet availability is not a prerequisite to effective CCCM use, it did help students in making the concept maps more effective, diverse and attractive. For example, by inserting photos and additional information from websites and blogs.

4.4.8. Barriers in using CCCM in science classrooms

The two science teachers were asked to identify barriers that could impede CCCM use in their classrooms. Again, both teachers identified and reported barriers associated with the science teacher, the students and the school. These are presented in the following sub-sections.

4.4.8.1. Barriers related to science teachers

Both teachers identified teacher expertise as an issue related with the effective use of CCCM in their classrooms. Suspicion and lack of a positive attitude towards CCCM use was the first barrier identified by Jai. Jai also mentioned the science teacher's confidence and experience, which if limited, could work as barriers in implementing the CCCM effectively. He further added that, "*teachers' lack of expertise and knowledge of the content and* [of their] *students, are some other factors related with the effective CCCM use*". Lata also indicated the expertise on the part of the science teacher, stating:

As I mentioned earlier, a teacher should have a good knowledge of the concept mapping and experience in using the software. A lot of the effective use depends upon the mastery of the science teacher of the content and his ability of implementing the technique or software. These things can either make the CCCM use more effective or less effective (Lata-Tr2Sch2Int).

Thus, both teachers focussed on the expertise of the science teachers and highlighted it as a major factor (barrier) affecting the use of CCCM in science classrooms. Some other barriers mentioned by the teachers were teachers' lack of knowledge and awareness of instructional strategies, lack of understanding of students' beliefs and experiences. Lack of motivation, encouragement and feedback were also identified as some important barriers related to teachers in terms of CCCM use.

4.4.8.2. Barriers related to students

Neither of the science teachers specially mentioned any factor related to students when asked about the barriers to CCCM use, although both of them highlighted the importance of students' understanding of science concepts and their relationships. Teachers predominantly reported many factors that could support CCCM use in their classrooms. From the support aspect, important factors identified that could possibly affect the use of CCCM in classrooms were students' understanding of the importance of using CCCM, interest and motivation towards science learning. Lack of these aspects could be a barrier in the effective use of CCCM in science classrooms.

4.4.8.3. Barriers related to the school

Although the number of students in Jai's class (57) was less than that of Lata's (67), class size was the first barrier that was identified by Jai, whereas Lata did not mention it. Both teachers pointed out that an insufficient number of computers and software was a barrier, even though there were sufficient computers (32 and 40) in both schools. Jai highlighted the issue of availability of the computer lab for his class as he had to use the language lab during most of the time the *teaching experiment* took place. Jai also pointed to lack of the support from the ICT instructor. Jai stated:

The, uh.., if the classrooms are overcrowded and there are large numbers of groups [Res: Hmm...hun], then it is a hindrance. And also, if you don't find enough computer systems and/or if the software is not installed on enough *numbers of computers [Res: right], that make another hindrance in this technique (Jai-Tr1Sch1Int).*

Lata also reported similar experiences in relation to the barriers faced or perceived in the use of CCCM in her classroom. She stated:

As far as the difficulties are concerned, the attitude of the school, especially the head and teachers can make a difference. Then, access to the computer lab is another concern, especially when it is booked for another class. The cooperation of the computer lab assistant is uh… another difficulty if it is not there. Lack of access to internet and lack of enough software on sufficient computers are some of the main barriers (Lata-Tr2Sch2Int).

Some additional factors (barriers) affecting the use of CCCM in science classrooms were identified by both science teachers. These were: lack of positive and presence of sceptical attitudes of school principals and teachers towards CCCM use, and lack of funding for the purchase of software that could hinder the CCCM use in their classrooms.

4.5. Students' focussed group discussion results

As described in sections 3.6.5 and 3.8.5 of chapter 3, two focus group discussions were conducted with some students from both intervention groups. The main aim of these focus group interviews was to capture a detailed account of students' perceptions and experiences about CCCM use in their classrooms. In this way, these focus group interviews provided another tool to evaluate the impact of CCCM on conceptual learning and motivation towards science learning from students' perspectives. These focus groups also provided important information about the enablers and barriers of using CCCM in secondary science classrooms from students' perspectives.

Students' focus group discussion transcripts were analysed to identify information related to the eleven identified themes in the teachers' interviews and the two research questions: 3 and 4 of the study. Relevant comments (direct quotations) from the focus group members are presented to describe the results. In addition to the eleven themes outlined in section 4.4, the only additional theme presented here is students' knowledge of concept mapping and the process of making a good concept map. These results are presented in the following sub-sections. Similar to the teachers' interview findings, the direct quotations from students' discussion are displayed in *italics* fonts.

4.5.1. Students' knowledge of concept mapping

The first question of the focus group interview was to explore what students knew about a concept map and concept mapping. Students were asked to define a concept map and to explain how they could construct a good concept map. Both groups demonstrated a good understanding of the definition and the ways to construct a good concept map. Group N[15] students defined a concept map in terms of the essential elements and characteristics while group T tried to define it more like an expert definition. The following direct quotation presents some thinking from group N students.

> *Neel: Sir, first of all uh…, it is a map of concepts, clear and meaningful and linked by major and minor concepts [Res: OK], and start with major concept and then minor, then uh.., …*
>
> *Nand: [Connecting words…*
>
> *Neel: […. Then linear map [Res: OK]. Then, after that we can insert images and examples.*
>
> *Res: All right. Any other? Ok, any other who can tell me what a concept map is? [Collective response: Not clear words]. Namo, Nand, anyone?*
>
> *Nita: Sir, concept map is a clear and meaningful connection …*
>
> *[WORD]*
>
> *Namo: Sir, it is like a roadmap, like a map of India, hmm…, like different roads leading to different cities*
>
> *Res: So, what is the similarity?*
>
> *Nisha: Sir, no sir it is clearer than that [(unidentified)*
>
> *Neel: [it is clearly understandable*

[15] The two groups *N* and *T* in the focus group discussion findings refer to the two sub-groups of 5 students each and actually belong to the two intervention groups (classrooms) A and C. These are named as group 'N' and 'T' just to differentiate from larger groups A, B, C and D. All the pseudonyms in group *N* start with letter N and all names in group *T* start with letter T.

[Nita: yes sir …

Res: If you mark the roads on the map, like this road leads to Delhi, this one leads to Chandigarh, that one leading to Karnal etc, it will be clear as well.

[WORD]

Namo: [Sir, this is for better understanding

[Nand: yes sir.

Res: so, how will you define a concept map?

Neel: Sir, a concept map is a map of concepts and sub-concepts, uh.., linked with clear and meaningful connections and presented to understand a topic and can show understanding.

Res: OK, good. (GpASch1FGD)

Group T students defined a concept map as "*a graphical tool which is used to show knowledge about the concepts and their relationships and to present understanding about the concepts*". Some students across both groups equated the concept map with a road map while others compared it with a flowchart and a line diagram.

When asked how students could create a good concept map, group N students stated the process in terms of some features of a concept map, for example, major and minor concepts, hierarchy of concepts, meaningful connections, examples, and illustrations and photos, and stressed that they needed a group to make a concept map. Whereas group T students put emphasis on the group discussion and understanding of the concepts and their relationships before making their individual maps. These students mentioned that they first discuss their individual maps and then finally prepare the group concept map which they correct and refine with the help of their teacher. Therefore, students from both the groups revealed a good understanding of the meaning, definition and process of constructing a good concept map from their own points of view.

4.5.2. Students' views about the use of concept mapping

A part of research question 3 was to investigate how secondary students perceived CCCM use in their classrooms. The students in the two focus groups were asked to talk about their experiences and perceptions of CCCM use. Both group of students revealed a positive attitude towards the use of the intervention and reported that they enjoyed learning science with concept mapping in small groups.

Group N students mentioned that CCCM has helped them to a good extent to learn and understand science concepts and has enhanced their interest and confidence about science learning. Group N students also mentioned that they had tried CCCM in other subjects and their science teacher had used it for testing their knowledge and understanding on different occasions. Group T students mentioned CCCM use in terms of a tool for note taking, revision and pointed to the changes, for example, increased discussion and interaction in their classroom, that the use of CCCM had caused. The following excerpt of the interview transcript reflects group T students' views of CCCM use:

> *Teena: We can add different viewpoints and thinking to construct a concept map, and it can also be used to learn, to revise the subject matter and if we keep notes it makes the revision easy and understandable.*
>
> *Tuli: And it provides a good help in understanding science. It is very easy to learn.*
>
> *Teena: [it makes connections between what we know and what we need to learn and to understand.*
>
> *Res: Ok, Ok. Good. You wanted to say something Tarang? About the use of concept mapping in science learning*
>
> *Tarang: Sir, we usually use it for revision of a chapter and our teacher asks us to prepare concept maps for unit tests. (GpBSch2FGD)*

A student (Teena) in above quote mentioned an innovative use of CCCM in terms of a tool to check prior knowledge of the concept and what they need to learn to master a concept. This was an additional use to the earlier mentioned uses of CCCM by teachers: as a method of teaching, assessment, note taking and revision, and which is an important aspect of learning. When asked about one specific use of CCCM in science teaching and learning, most of the students from both groups stated that the intervention can be used as a method of assessment in addition to its use as a method of teaching and learning.

4.5.2.1.   CCCM versus other methods of teaching-learning

The focus group students were asked to reflect on their perceptions and experiences about the differences that they noticed between CCCM and other methods they had used previously for science learning in their classrooms. Students from both focus groups mentioned some methods such as lecturing, questioning, and project work which they used previously in their classes, and stated some differences between CCCM and other methods. Both groups of students preferred CCCM over other methods of teaching and learning science mentioned by the researcher. Group T students stated that the intervention had enhanced their interest through providing more opportunities to discuss, debate, add, agree, disagree and interact with each other in their groups. The following quote from group T students indicates their preference and reasoning:

> *Teena: It is a very good method of learning science; it is a better method.*
>
> *Res: [better than what?*
>
> *Teena: Sir, better than lecturing and other methods.*
>
> *Res: why is it better than other methods?*
>
> *Tara: Sir, We have more opportunities for discussion and interaction. We can learn from our friends and um…*
>
> *Tarang: [sir, it is a better method to understand science.*
>
> *Res: [can you mention any incident or example when you find it better than other methods? When you understand something better using concept mapping than reading a book?*
>
> *Collective response: [WORD]*
>
> *Teena: Sir, we found it very effective in studying the mole concept and the classification of the living organisms. We understood these topics better than when we read the chapters from the NCERT [publication] book.*
>
> *Tapas: Sir, it helps better understanding. (GpBSch2FGD)*

Group N students mentioned that they had used methods of working in a group such as project work, but they did not find them as interactive and interesting as CCCM. They stated some of the benefits of CCCM in terms of more discussion, peer learning and support, focus on learning, accountability of members, and support and feedback from the science teacher. Therefore, most of the students from both group expressed positive attitudes and preferences towards CCCM over other methods of science teaching and learning.

4.5.2.2. CCCM and conceptual learning

All the students from the two intervention (focus) groups believed that the use of CCCM in their classrooms could enhance their learning and understanding of science concepts to a considerable degree. Students mentioned that they had perceived CCCM to be very useful since the very first day of its implementation. Most of the focus group students agreed that the use of CCCM changed their focus from just learning and memorising to understanding of the concepts. Students recalled many incidents when they successfully understood science concepts by discussing them in groups and preparing concept maps. They recalled the learning of some difficult concepts such as the *Mole Concept* and *classification of organisms* which required a substantial amount of prior knowledge before understanding these concepts. Group N students recalled an incident:

> *Res: Can you mention a time when you completely understood a concept using CCCM in the group?*
>
> *Nisha: Sir, I remember when Namo and Nand found it extremely difficult to understand the mole concept, Neel and I helped them to understand using many simple illustrations which are not available in the textbook and not used by our teachers. Luckily, we found them from internet and told our teacher about them.*
>
> *Neel: [Sir, we even presented them in front of the whole class when most of the students were struggling to understand the concept.*
>
> *Res: OK. Good.*
>
> *Nand: [Yes sir, I found the illustration very helpful to understand the mole concept and other topics also.*

Namo: Sir, I found the group work very supportive to improve my thinking and analysis skills. (GpASch1FGD)

Students from both of the focus groups perceived the skills of comprehension, explanation, analysis and synthesis to be important and useful for understanding of difficult science concepts. Students stated that they learned many things from their peers while working in groups. All of the focus group students agreed that CCCM use had enhanced their conceptual learning of difficult science concepts.

4.5.2.3. Effectiveness of CCCM in addressing misconceptions among students

The focus group students were asked whether or not CCCM could address misconceptions, and if so, how effective was CCCM in doing this. The majority of these students reported that CCCM had helped them at one time or another to address their misconceptions. Group N students mentioned that their science teacher used the concept mapping technique to identify their misconceptions and to inform them about those conceptions, and then suggested spending more time on those misconceptions. They revealed that the group work played an important role in the process of finding and correcting misconceptions. Students emphasized the crucial role of their peers and teachers in correcting their misconceptions. Group T students stated that their science teacher had put special emphasis on the correction of misconceptions to facilitate conceptual learning. Group T students reported that there had been many incidents especially when learning difficult concepts when their teacher initially worked with different groups and later with the whole class to clarify their misconceptions.

4.5.3. CCCM and classroom learning environment

The focus group students were asked to reflect on some aspects of their classroom learning environments, for example the role of the teacher, relationships among students and between teacher and students, and social and psychological aspects. Students from both of the focus groups expressed positive experiences related to their classroom environments and outlined different factors that could affect those learning environments. Students remarked that their classroom learning environments had been very comfortable and students felt very relaxed, included, respected and valued in their classes most of the time during the intervention period. Findings related to some of these aspects are presented in the following sub-sections.

4.5.3.1. Role of the teacher

Most of the focus group students agreed that a science teacher could play an important role in encouraging students and creating motivating classroom environments. Group N students stated that their teacher had persistently helped to ensure the process of collaborative learning went smoothly. These students described their teacher as being very encouraging and motivating. These students mentioned that their teacher acted as another student in the classroom and they noticed a huge change in the role of the teacher while using CCCM in their classroom. Most of the students perceived the teacher as a helper, coach and motivator. Similar experiences were reported by group T students, who also observed enormous change in the role of their classroom teacher. The following excerpt from the focus group discussion with group T presents some of the findings about the role of the teacher:

> *Tara: Yes sir. There was more discussion in the classroom than earlier, and more freedom in the discussion…*
>
> *Res: [Can you explain that more freedom in the discussion?*
>
> *Teena: All students are…*
>
> *Tara: [Sir, the teacher treat all children equally and interact well with all. It is like if someone doesn't know something, our teacher encourages all to participate and to ask questions and answer all equally. Teacher gives importance to all and students feel valued in the classroom. [Tapas wanted to add something here]*
>
> *Res: [OK, what do you think about it Tapas?*
>
> *Tapas: Sir, there is more discussion in the group and there is more freedom to work as you want [as you like to construct a concept map], teacher displays very friendly attitude.*
>
> *Tarang: [Sir, everyone feel responsible for the group work as well as for their own work…*
>
> *Res: What do think Teena about it?*
>
> *Teena: Sir, students can question, suggest and complain about anything that is not working for the group. All students feel respected included in the class. (GpBSch2FGD)*

Therefore, students reported being treated equally, being respected and being provided with the freedom to work as they wanted and to ask questions for clarifications. Students recalled and mentioned some incidents when their teachers treated them equally and made them understand the concepts by explaining them nicely in their classes. Other aspects related to the teacher's role as mentioned by students were providing freedom, autonomy and shifting responsibility towards students. Both group of students predominantly agreed with the role of the science teacher as organiser of learning and discussion and providing opportunities for maximum learning.

4.5.3.2. Relationships in the classroom

Students were asked to reflect on the relationships they shared with their peers, other classmates and the teacher. Most of the students perceived the relationships (student-student and student-teacher) of paramount importance for the creation of effective learning environments. In relation to student-student relationships, group N students mostly reported the relationship as positive, supportive, encouraging and progressive. Students mentioned that their peers helped them to a great extent to succeed in their learning and bright students took responsibility for the success of the weak students in the groups. Group N students perceived a very positive and encouraging relationship shared by their science teacher. These students mentioned that their science teacher had been very friendly, caring and motivating in the class. During the group interview, one student stated, "*we don't feel scared if we do not know anything or if we need to ask again and again for explanations*". Another student perceived the relationship in terms of trust and mentioned, "*Our teacher trusts us and lets us work in groups without constantly checking, and it is our duty to work properly and develop more trust*".

Most of the students from group T perceived the relationship between them and the teacher as very positive. However, some of them were negative regarding several aspects of the relationship. Students stated that while there was very good support and interaction within their groups the interaction between different groups was lacking. The teacher did not allow working with other groups and students were confined to their group members for the duration of the teaching experiment. One student from group T mentioned that the teacher showed authority and was not very friendly, whereas others appeared to be in disagreement with him. This student commented that the teacher should treat all students equally and listen to all students. Another student highlighted the support and feedback they received from their teacher. She mentioned that the feedback provided by their teacher was neither timely nor in detail. Therefore, there were mixed reactions to the relationship aspects of the learning environment.

4.5.3.3. Teacher change

Students were asked if they observed any change in their teachers' behaviour, practice or activity due to CCCM use in their classroom. Students mentioned many changes related with different aspects of how teachers worked in the classroom. The main change that most of the students mentioned was in the teacher's role in the classroom, which they had observed on several occasions. Students stated that they felt the teacher was a sort of a "knowledge reservoir" prior to CCCM and they never questioned that knowledge authority. After using CCCM, students found their science teacher more friendly, caring, supporting and motivating. Students reported an increase in the support and positive attitude of the science teacher.

Another change that students reported was in teachers' practice in the classroom. Students mentioned that they noticed an increase in the group work and collaborative activities which had not been that frequent before in their class. Some students mentioned that their class teacher started using CCCM for many different purposes, such as for assessing students' prior knowledge, for formative assessment like unit tests, and for revision of the units. Students also mentioned changes in some other aspects of the learning environment, for example, a change in focus on understanding, moving from rote learning of facts and procedures to understanding the concepts. A transfer of power and responsibility in terms of providing freedom and autonomy to students, so that everyone feels comfortable, included, respected and progresses in their studies, was also highlighted.

4.5.3.4. Overall experience of using CCCM in science learning

Students were asked to reflect on their experiences of working in small groups and using CCCM in their learning of science concepts. Students revealed many benefits of working in small groups. Some of the benefits students mentioned were peer support, more freedom and autonomy, a focus on understanding, and responsibility for learning and understanding. When asked if they found any differences between working in groups and working alone, most of the students cited many differences between them and preferred working in groups over working alone. The correction of mistakes, improvement of the concept maps, understanding of the concepts and more discussion were some of the main advantages of working in a group that students reported.

4.5.4. Factors affecting the CCCM use in science teaching and learning

Students were asked to talk about the factors that could either support or obstruct the use of CCCM in their classrooms. They revealed many factors related with peers, teachers and schools that could enable or hinder the use of CCCM in their classrooms. These factors are reported in the following two sub-sections.

4.5.4.1. Students' views about enablers for using CCCM in classrooms

The majority of students from the two focus groups perceived peer support as the primary requisite that was required for the effective use of CCCM in their classrooms. Students mentioned that the more they interacted and discussed with their peers the more they learned and understood. All of the group N students agreed that they had strong peer support and healthy discussions most of the time, whereas group T students pointed out the need to improve the peer support and feedback. The other factors highlighted in relation to peer support were the relationships, responsibility, trust, collaborative efforts and a positive attitude towards learning of the group members. Some students suggested ways to improve peer relationships for the successful implementation of CCCM intervention in their classrooms. For example, group T students reported the need to develop trust and support among group members.

The role of and support from the science teacher was the second most important factor revealed by the students that could affect CCCM use in their classrooms. Group N students stated that their teacher had gone extra mile to help students, and ensured the focus on understanding of science concepts. In contrast, group T students reported that their teacher had favoured some sub-groups over others in terms of providing support. These students expressed the need for a positive attitude and impartial support from the teacher for effective CCCM use in their classroom.

Students seemed unaware of the factors related to schools that could support CCCM use in their classrooms. Only one student from group N mentioned the availability of sufficient computers and the software in the computer lab. Some students stated that the classroom learning environment and communication between teacher and students could affect the successful use of CCCM. These students mentioned that the classroom environment was very comfortable and conducive for learning most of the time during CCCM use. Some other factors perceived and highlighted by students that could play an important role in the successful use of CCCM in their classrooms were students' interest, motivation, prior knowledge and experiences, and teachers' feedback and reinforcement.

4.5.4.2. Students' views about barriers of using CCCM in classrooms

Most of the students, at different points in their interviews, identified lack of support as a barrier to CCCM use in science teaching and learning. For instance, some of the group T students mentioned lack of peer support and poor attitudes as barriers to the process of collaborative learning. Other student-related barriers identified that could hinder the successful use of CCCM in science classrooms were students' interest and motivation, attitudes towards group work, students' knowledge and intelligence, as well as the structure of the group.

Some students reported that the lack of an appreciative attitude of the science teacher and paying equal attention to all could be other significant factors that could hamper CCCM use in their classrooms. Other teacher-related factors highlighted by students were: teachers' lack of expertise in handling of the software, and time and class management skills. Some students reported that the pacing of lessons and the difference between the planned time and actual available time for a unit/chapter could also affect CCCM use in classrooms. Lack of support from the school principal and availability of the computer lab, sufficient computers, internet connection, and software were some of the school-related barriers highlighted by students in their group interviews.

4.6. Summary of teachers' and students' views

Both students and teachers expressed a predominantly positive attitude towards CCCM use in their classrooms. Teachers' perceptions of CCCM use included using it as a teaching and learning strategy, as a teaching aid, as a tool to assess prior knowledge and finally as a diagnostic and formative assessment tool. Students' perceptions included some additional uses of CCCM such as a note taking tool and providing information about their current knowledge and what they needed to learn further. Both teachers and students agreed on the role of CCCM in creating interest, engaging students and thus motivating students to learn conceptually. Although both of the teachers had experienced and tried group and collaborative work previously in their teaching careers, they mentioned that they found CCCM use very different from the traditional methods in terms of interaction, discussion, ground rules, roles, relationships, responsibilities and focus. Students mentioned some additional benefits of CCCM use, such as peer learning, peer and teacher support, more interaction, improved engagement, more discussion and enhanced self-confidence. Both teachers and students preferred CCCM use over other methods of science teaching and learning because of the perceived benefits. Both teachers and students perceived an important role for CCCM in enhancing conceptual learning and addressing misconceptions. They recalled many incidents when students either struggled to understand difficult concepts or helped each other to find and correct misconceptions. Students emphasized the crucial and critical role of peers and action taken by teachers to address misconceptions.

Both teachers and students reported changes in the teachers' roles, behaviours and practices, and in teacher-student and student-student relationships. Both of the teachers reported that they had observed and experienced many changes in their roles and teaching practices as a result of CCCM use. Jai considered himself as another learner in the class in addition to his role of a facilitator, coach, guide and motivator. Lata also reported the same experience but students contrasted her views stating that they got unequal and biased treatment from her. In relation to teacher-student relationships, one group of students mentioned that they found the teacher was very friendly, caring, and easily approachable, of a respectful nature and provided timely feedback, and showed trust and confidence in them. The group of students, from the other class, reported that their teacher was not friendly, showing authority, less interactive and not providing timely and detailed feedback. Both of the teachers and most of the students reported mainly positive and friendly relationships among students. Teachers mentioned that CCCM use encouraged trustworthy and respectful relations among students because it provided more opportunities to interact and discuss, and it provided more freedom and autonomy in their learning. Some students reported the development of positive, supportive, encouraging and progressive relationships while others complained about the lack of interaction among different groups because of restrictions imposed by their teacher.

Both teachers reported many changes in their beliefs and practices. Both teachers mentioned that they had developed a firm belief in the potential of CCCM as a better method of science teaching and learning. Jai pointed to the change in his focus to understanding concepts from that of rote learning and memorisation, and his familiarity with concepts like assessment for learning and effective feedback. Lata reported that after using CCCM, she became familiar with different theories of learning, collaborative learning activities and affirmed the important role that CCCM could play in developing constructivist learning environments. Students also experienced and reported a change in the teacher's role, from a knowledge authority to that of another friend, peer, guide and a coach. Students pointed to the increased teacher support and positive attitudes. Some students identified a change in teacher practices in terms of increased use of group and collaborative work, increased and multipurpose use of CCCM as a tool, and the transfer of power and responsibility to students in terms of freedom and autonomy in their learning.

Teachers and students reported complementary views related to the factors that could either promote or impede CCCM use in their classrooms. Teacher-related factors mentioned by teachers were expertise and appropriate use of CCCM as a technique as well as concept mapping software. Teachers also mentioned teachers' knowledge of science concepts, and students' beliefs, prior knowledge and experiences that could promote or hinder the CCCM use. Students put more emphasis on a positive teacher attitude, relationships and interaction between the teacher and students. Lack of an appreciative attitude and trust of the teacher, time management and pacing of lessons and lack of trust were some other factors identified by students. Student-related factors mentioned by teachers were students' attitudes, interest, knowledge and awareness of the importance of the use of CCCM. In contrast to teachers' views, students' perspectives stressed support from their peers and teachers as enablers. One group of students reported the presence of strong peer and teacher support, whereas the other group pointed to the lack of support and indicated a need to improve peer as well as teacher attitudes. Students also mentioned that the group structure or composition could promote or hinder CCCM use. Productive discussions, mutual trust and accountability among group members and responsibility for others' learning were additional factors mentioned by students. Only teachers reported some school-related supports or barriers (or lack of support). These factors ranged from the attitude of, and support from, the head, ICT instructor, and other staff; to the availability of the computer lab, sufficient computers, availability of software and internet connections. The class size was mentioned by Jai who had fewer students than the one who seemed unaware of it (or may be was not worried about it). Students also identified some similar factors related to the computer lab and software as those reported by teachers.

This chapter presented findings in relation to the four research questions of the study. The achievement test (ATS9) results produced evidence both of students' improved science achievement and conceptual learning. The results also suggested an enhancement of secondary school students' motivation towards science learning. The results from the teacher interviews and student focus-group discussions organised around the major themes aligned with research questions 3 and 4 were presented after that. The results from teacher and student interviews predominantly presented positive and favourable attitudes. These results indicated the important role that CCCM could play in enhancing conceptual understanding by addressing misconceptions and promoting interactions and positive relationships in the classrooms. In the next chapter, a detailed discussion of the results obtained from the achievement tests (ATS9), the motivation questionnaire (SMTSL), concept maps, and teachers' and students' interviews is provided with reference to literature and the aims of the study.

Chapter Five. Discussion

The previous chapter presented the results of this study. This chapter provides a detailed discussion of the results organised around the four research questions of the study. As Evans, Gruba, and Zobel (2014) mention the main purpose of a discussion chapter is "to establish what can be concluded from these results" and that it is the place where the researcher "can advance from information to knowledge" (p. 113). In this regard, this chapter is intended to make sense of the comprehensive information presented in the previous result chapter. Interpretations and discussion of these results is presented in relation to the context of the study and the reviewed literature in chapter 2. The main aim of this study was to investigate the effectiveness of the intervention: Computer-based Collaborative Concept Mapping (CCCM) on Indian secondary school students' science learning and motivation towards science learning. Other objectives, implicit in this aim were: to study the effects of CCCM on science achievement and conceptual learning, to investigate teachers' and students' perceptions of CCCM use and to examine the enablers for and barriers to CCCM use in Indian secondary science classrooms. The results were presented in the sequence of the four research questions of the study. The discussion is presented in the same sequence in this chapter. The impact of CCCM on students' science learning and motivation is discussed in the first part of this chapter and teachers' and students' views of CCCM use are discussed in the latter part.

5.1. CCCM and science learning

The first research question of the study was to investigate the effects of CCCM on Indian secondary school students' science achievement and conceptual learning. The two research hypotheses H_1 and H_2 related to research question 1, as stated in section 2.9 of chapter 2, that "*CCCM affects science achievement of Indian secondary school students*" and "*CCCM affects conceptual learning of Indian secondary school students in science*", are examined in relation to the findings presented in chapter 4. The overall results obtained for science achievement (see Tables 4.5, 4.6 and 4.7) and conceptual learning (Tables 4.8 to 4.13) reject both the null hypotheses H_{o1} and H_{o2} and accept the two related research hypotheses H_1 and H_2. The enhancement of students' science achievement is evident from the higher achievement mean scores of the experimental group students, confirmed by the ANOVA test and the t-test results obtained from the Achievement Test in Science for grade 9 (ATS9). The improvement in conceptual learning is evident from the higher percentages achieved (Tables 4.10 and 4.13) and the t-tests results (Tables 4.8, 4.9. 4.11 and 4.12) for LOCS and HOCS[16] responses which are in favour of experimental group students. The conceptual understanding is also evident from the nature of responses (samples displayed) on ATS9 answer sheets and the quality of the group concept maps (section 4.2.3). Moreover, the comments made by the participant teachers as well as students during interviews also confirmed a positive impact of CCCM on conceptual learning. Therefore, both the quantitative and qualitative findings indicate that CCCM has the potential to enhance conceptual learning and hence science achievement of secondary school students. The concept maps constructed by students in the intervention groups provided valuable information to examine and contrast group learning with individual students' learning. These findings about the improved science achievement and conceptual learning of the intervention group students are discussed in the following sub-sections.

5.1.1. CCCM and science achievement

A part of research question 1 (section 2.8) was to investigate the impact of the CCCM intervention on Indian secondary school students' science achievement. The findings from both the quantitative and qualitative data analysis suggest that CCCM was effective in helping the intervention group students learn science concepts and enhance their achievement scores. The results from students' achievement test ATS9 (refer to Tables 4.5. 4.6 and 4.7) suggested that there was a statistically significant difference between the science achievement of the intervention and comparison group students. This means that students who studied science using CCCM performed better on the ATS9 and scored more than those who studied science using traditional learning and teaching methods, which usually are based on lecturing and listening to teachers. The participating teachers and students also commented, in their interviews, on the effectiveness of CCCM in enhancing students' science learning and achievement. These findings are consistent with the findings reported by some Indian researchers in the field of school science education, for example Reddy and Subbaiah (2014), V. Padmanabhan

[16] LOCS and HOCS: Acronyms for Lower Order Cognitive Skills and Higher Order Cognitive Skills

and Marathe (2013, September), Dhaaka (2012), Chako (2009), and Rao (2004, December). These researchers report an improvement of science achievement as a result of concept mapping, although not CCCM as an intervention as a whole. At the international level, most of the studies on concept mapping have reported a positive impact of the use of concept mapping and related interventions on science achievement. Research, for example by Basque and Lavoie (2006), Basque and Pudelko (2010), Buntting (2006), Greene (2011), Kwon (2006), Lin, Wong, and Shao (2012), Nesbit and Adesope (2006), Novak (2010), Pérez Cabaní and Bosch (2010), Soong (2010), Udeani and Okafor (2012), van Boxtel et al. (2002), and Jang (2010) confirm the positive impacts of concept mapping and collaborative concept mapping on science learning and achievement.

As reported in the literature review (sections 2.5.1 and 2.5.2), the effect of concept mapping on science achievement is well documented by many researchers through meta-analyses and long-term and short-term research studies. Professor John Hattie (2009), in his book *Visible learning: A synthesis of over 800 meta-analyses relating to achievement* reported an average effect size (ES) of 0.57 for concept mapping and placed it in the *zone of desired effects*, which according to him is the range of influences above the hinge-point[17] (*h-point*) on the continuum of effect sizes. Another meta-analysis by Nesbit and Adesope (2006) reported an average ES of 0.60, identifying differences in terms of whether students constructed the concept maps themselves (d = 0.82) or studied the concept maps prepared by teachers (d = 0.37). Contrary to Nesbit and Adesope's research, a meta-analysis by Kim, Vaughn, Wanzek and Wei (2004), however, has reported higher effects when teachers constructed the concept maps (d = 1.15-1.20) than when students generated them (d = 0.86). Similar effects of concept mapping were reported by an earlier meta-analysis by Horton, McConney, Gallo, Woods, Senn, and Hamelin (1993) in terms of an average ES of 0.51 for the 19 studies analysed. An ES of 0.66 was found for individual construction of concept maps while for group construction of concept maps the ES was found to be 0.88 (Horton et al., 1993).

[17] Hinge-point, according to Hattie (2009), "is the point on the continuum [of effect sizes] that provides the hinge or fulcrum around which all effects are interpreted" (p.16). It is a set benchmark at d = 0.40 (the average effect size), above which the effects are worth considering. It is important to note that any influence on achievement is measured relative to this h-point of d = 0.40 and not to d = 0.0.

However, there are some studies, for instance Adlaon (2012), Skidmore (2008), Rabie (2007) and Pickens (2007), that report no significant difference between the experimental and control groups. These studies further point out many possible reasons to explain and describe this seeming lack of significance: for example, the duration of treatment, the expertise of teachers/tutors, and students' and teachers' attitudes and motivation. Furthermore, in the case of collaborative concept mapping, some researchers speculate about the major role played by collaborative activities rather than the actual effect of concept mapping and conclude that the concept mapping itself might not affect science learning and achievement. These explanations and speculations are important to consider for examining the actual impact of concept mapping in different situations.

In relation to collaborative (group or dyad) concept mapping (CCM), the Nesbit and Adesope (2006) meta-analysis found an ES of 0.96 for group learning while it was 0.12 for individual learning using concept mapping. Another review of research carried out by these authors (Adesope & Nesbit, 2010) reported a large ES in favour of CCM and concluded that "collaborative concept mapping is an effective learning activity" (p. 246) when compared to other learning activities such as lecturing, writing summaries, outlining and group discussion. Adesope and Nesbit (2010) speculated/commented that the effects might be due to the more interactive nature of CCM and the extent of collaboration in the experimental groups. Whatever the reason, CCM has also been reported as an effective intervention to enhance learning and achievement by many other researchers (Cañas et al., 2003; Chaka, 2010; Cheung, 2006; Novak, 2010; Okebukola, 1992; Pérez Cabaní & Bosch, 2010; Roth & Roychoudhury, 1993, 1994; Torres, 2010; van Boxtel et al., 2002). However, among them, very few have investigated computer-based CCM in face-to-face situations as is the case of this research.

As reported in section 4.1.3, the effect size of 0.74 obtained for the science achievement in this study implies that about 77% (CohenU_3) of students in the intervention group (CCCM) achieved above the mean of the comparison group students. In other words, an average intervention group participant outperformed 77% of the comparison group students. In terms of probability of superiority, it means that there is 70% chance that a student picked at random from the intervention group will have a higher score than a student picked at random from the comparison group (Ellis, 2010). These results about the experimental groups achieving higher than control groups, are in agreement with the Indian and international research studies discussed at the beginning of this section. Further discussion and explanation of these findings is presented in section 5.1.3 along with CCCM impact on conceptual learning.

5.1.2. CCCM and conceptual learning

The second part of the research question 1 (section 2.9) was to examine the effect of CCCM on Indian secondary school students' conceptual learning in science. As suggested by the Adesope and Nesbit's (2010) meta-analysis, that there is a "need to investigate the effects of collaborative concept maps on higher level cognitive processes" (p. 249), such as comprehension, application, analysis and evaluation. This research, therefore investigated the effects of CCCM on secondary students' conceptual and procedural knowledge along with the effects on achievement and factual knowledge. To study the effect of CCCM on different types of knowledge dimensions and cognitive process dimensions, the ATS9 data were quantitatively and qualitatively analysed. The two categories of items (LOCS and HOCS; details in section 3.6.1), which were intended to assess students' conceptual and procedural knowledge were designed and discretely analysed. Findings from this study demonstrated that CCCM has the potential to enhance the conceptual learning of Indian secondary school students. The results obtained for the LOCS and HOCS items (Tables 4.8 to 4.13) of the ATS9 confirmed that the CCCM intervention enhanced the conceptual and procedural knowledge of Indian secondary school students in science. To elaborate the differences between the individual students' and group learning as a result of CCCM, the responses obtained on the ATS9 response sheets were analysed against the concept maps constructed by the intervention group students. These findings about the consistency in the group and individual learning also confirmed that the CCCM has improved students' individual conceptual learning. This potential of CCCM was also confirmed by the interview findings from the two science teachers' interviews and students' focus groups. Therefore, the results presented in sections 4.2, 4.4.3 and 4.5.2.2 suggest that CCCM has the potential to enhance students' conceptual learning, including lower-order and higher-order cognitive skills.

The improvement of students' conceptual learning in science by concept mapping and collaborative concept mapping is well documented in the concept mapping literature. Researchers such as Kharatmal (2009), Buntting (2006), Kinchin (2000) and Torres, Forte, and Bortolozzi (2010) have suggested a positive impact of concept mapping on students' meaningful learning in science. Collaborative concept mapping has also been reported to impact the conceptual learning and understanding of science (for example, Immonen-Orpana & Åhlberg, 2010; Jang, 2010; Lin et al., 2012; Roth & Roychoudhury, 1994; Torres, 2010; van Boxtel et al., 2002). Findings from this study are consistent with the findings from these studies. However, most of the earlier studies carried out investigated the effect of CCM on lower-level cognitive skills and processes (for example, on factual learning, remembering, retrieving and comprehension) rather than on the higher-level cognitive thinking (for instances, the process of analysing, synthesising, applying, evaluating and creating) as proposed by Krathwohl (2002). The findings from this study propose to fill this gap and analysed the group as well as individual conceptual learning in detail.

5.1.3. Possible explanations regarding the findings

The results obtained related to research question 1 and the brief discussion provided in the previous two sub-sections suggest that CCCM has the potential to enhance science achievement as well as conceptual learning of secondary school students. Students' science achievement, in relation to this study, can be thought of comprising factual, conceptual, procedural and meta-cognitive knowledge. Many possible explanations and speculations can be offered in terms of interpreting the significant differences in achievement and conceptual learning obtained for these results. One likely explanation of these significant differences could be the type of learning intervention designed and used in this study. CCCM was designed by integrating the three teaching and learning strategies: computer-based learning, collaborative learning and concept mapping, which might have affected secondary science learning and achievement. There is a large literature base to verify the effectiveness of all these three learning-teaching strategies on students' science achievement. This possibility of the impact of either computer-based or collaborative learning is further reported by some researchers; for instance Kinchin (2000), Kinchin et al. (2005), Kwon (2006), Soong (2010) and Torres et al. (2010), who also used similar strategies or interventions in the school science context.

Another possible explanation for the differences obtained could be the design of CCCM; that is, the way the intervention was designed and implemented. The focus of the intervention design on science understanding and motivating students towards science learning, and the explicit emphasis on meaningful learning strategies, and selected motivation components (section 2.6.3) might have contributed to students' enhanced achievement and conceptual learning levels. It is important to remember that CCCM design is based in the *Learning Sciences* (Sawyer, 2014a) discipline; for example cognitive science, educational psychology, computer science, sociology, neurosciences, instructional design, design studies and information science. The design of the CCCM intervention was also based in the learning frameworks developed by research such as by the National Research Council (2005) and motivation frameworks proposed by researchers such as Brophy (2010b), Boekaerts (2002, 2010), Middleton and Perks (2014), Wentzel and Brophy (2014), and the National Research Council and the Institute of Medicine (2004), which might also have added to its effectiveness.

Another important explanation of the differences in the achievement and conceptual learning could be the nature of learning focussed and examined in the achievement test ATS9. For example, most of the studies which have reported positive effects of concept mapping on science achievement have either explored the learning for concepts which require mere memorisation or remembering of factual information (for instance, multiple choice questions or matching of the answers) or items which require much less conceptual understanding of the content. To verify this speculation and to study the conceptual learning differences acutely, t-tests for the two types of items: LOCS and HOCS, included in the ATS9 were carried out separately. The results obtained from these tests confirmed significant differences for the items which assessed the LOCS and HOCS. These findings are consistent with other Indian and international researchers for example, Buntting, Coll, and Campbell (2006), Chaka (2010), Kharatmal (2009), Kinchin (2000), Kinchin et al. (2000), Rao (2004, December), and Reddy and Subbaiah (2014).

In addition to the earlier mentioned explanations and speculations about the effect of the CCCM intervention on students' science learning and achievement, some other explanations of the improved performance should also be considered. The novelty effect of the intervention and the change in the classroom learning and teaching environment, for example, increased interaction, computer use, collaboration, increased students' autonomy, support and improved relations might also have affected the science achievement of the intervention group students. Moreover, the occasional presence of the researcher in the intervention classrooms during the training sessions, feedback sessions and covering for the teacher on the day the teacher was not present might also have encouraged students to do well and affected their science learning and achievement.

5.2. CCCM and motivation towards science learning

The second research question of the study was to investigate the effect of the CCCM intervention on Indian secondary school students' motivation towards science learning. The research hypothesis H_3, related to research question 2, and stated in section 2.10 of chapter 2, that "*CCCM affects motivation towards science learning of Indian secondary school students*", is examined in relation to the findings presented in chapter 4. Results obtained for the impact of CCCM on students' motivation towards science learning (Tables 4.14 and 4.15) suggested that the intervention group students who studied science using CCCM exhibited a higher level of motivation towards science learning than the comparison group students. Further analysis of data related to the motivation components (sub-scales) included in the *Students' Motivation towards Science Learning* (SMTSL) questionnaire revealed statistically significant differences for the four scales of *self-efficacy*, *active learning strategies*, *science learning value* and *learning environment stimulation* between the intervention and comparison groups (see Tables 4.18 and 4.19). Results for the remaining two component scales of *performance goals* and *achievement goals* were found to be not statistically significant. Overall, the results from the motivation questionnaire confirmed a positive impact of CCCM on the intervention group students' motivation towards science learning. These results were also supported by the interview comments made by the participant science teachers and students focus group interviews.

It is important to remember that unlike science achievement results, the results obtained for the SMTSL questionnaire were calculated from one intervention group only and not from both the intervention groups. The intervention group 2 (group C, figure 3.5 and 3.6) students were neither pretested for their motivation levels because of the research design nor were assessed for the equivalence of motivation levels unlike achievement. Therefore, the intervention group C students' motivation scores could not be included in the data analysis because of the lack of information about equivalence/homogeneity of the groups. Thus, the results for motivation toward science learning were based only on the data obtained from students of one school (intervention group A and comparison group B), who were pretested as well as post-tested for the motivation change using the SMTSL questionnaire.

The results for enhanced motivation are in line with the research carried out by Liu (2004), Keraro et al. (2007), and Butler and Lumpe (2008). These researchers found statistically significant differences in motivation between experimental and control groups, and concluded that collaborative concept mapping was an effective teaching strategy to motivate secondary students to learn. There are very few studies which have investigated the impacts of concept mapping and CCM on motivation and related concepts like self-efficacy and achievement or performance goals. Some studies, for example by Haugwitz et al. (2010), Hwang, Shi, and Chu (2011), Zhao (2003), Jegede et al. (1990), and Czerniak and Haney (1998), have examined the effectiveness of concept mapping and CCM on discrete components of motivation for instance students' self-efficacy, anxiety, interest and engagement. Most of these studies have reported enhancement of interest, self-efficacy and engagement, and reduction in anxiety of students as well as teachers. A very few studies have explicitly examined the comprehensive nature of motivation (including internal and external motivation, self-efficacy, self-concept, interest, goals and so forth) and related aspects as explored in this study.

Again, it is important to remember that, in contrast to earlier studies, this study has investigated the construct of *motivation to learn*, which according to Wentzel and Brophy (2014) is more *cognitive* in nature and "emphasize[s] its cognitive elements - the information processing, sense making, and advances in comprehension or mastery that occur when students are seeking to gain the intended benefits from a classroom activity" (p. 242). This cognitive aspect of motivation for science is seldom researched at the international level and has never been researched in the Indian context. Therefore, these results for *motivation to learn* science are another key finding of this thesis and add to the field of science education. The framework/model for conceptual learning and motivation in secondary school science, resulting from this thesis (Figure 6.1) describes these cognitive aspects as outlined by Wentzel and Brophy (2014).

In addition to the explanations and speculations presented for the enhanced learning findings in section 5.1.3, some further explanations can be offered. First, the novelty effect for both students and teachers could have motivated students and teachers to implement the intervention, which offered an entirely new and different instructional strategy to teach and learn science in Indian secondary science classrooms. A second possible justification for the positive impact of CCCM on motivation could be the explicit emphasis placed by the participant teachers and the researcher on conceptual understanding of science and motivational constructs; for example, value of the content, goals (mastery and performance), autonomy, competence and positive relations in the design and during the implementation period of CCCM. Similar findings about the impact of value and goals aspects in relation to enhanced motivation are reported by Shumow and Schmidt (2014), and Wigfield et al. (2009). A third possibility for the positive impact of CCCM on motivation could be the change in the learning environment of the intervention group science classes, especially the aspects of positive interactions among students, increased collaboration, the changed role of teachers and the feedback provided by teachers. Additionally, the more interactive nature of CCCM when compared with other classroom activities could have motivated students to do well, as identified by researchers such as Adesope and Nesbit (2010), Komis, Avouris, and Fidas (2002), and van Boxtel et al. (2002) who used similar interventions.

The positive impact of CCCM on motivation towards science learning can also be attributed to the relationships among peers/groups, as well as the relationship between teachers and students. For example, the peer support and care during the teaching experiment could have contributed to the positive impact of the CCCM intervention. This possibility of enhanced motivation by peer and teacher relationships is well documented by researchers such as Middleton and Perks (2014), Shumow and Schmidt (2014), Wentzel (2005a, 2005b, 2009), Wentzel et al. (2014), Wentzel and Brophy (2014), and the National Research Council (2003). Moreover, the two science teachers also confirmed these findings in their interviews, stating that they observed positive relationships among students and found students engaged and encouraged to learn science conceptually.

In the Indian school context, it is not surprising that the results for the two motivation component scales (achievement and performance goals) of the SMTSL questionnaire were found to be statistically not significant. In the Indian school context/society, competition is valued and promoted not only by peers, teachers and school principals, but also by parents and other relatives from the beginning of schooling. Parents, relatives and teachers coerce students to do better than their peers and all other students. Competition is stressed as the only way to excel in education and other activities of life. This is evident, from *National Science Olympiads* to very prestigious competitive exams, not only to get a job but also at any stage of admission, selection and progress. Therefore, these components of motivation to learn present a different picture than the one painted by studies by Ladd, Herald-Brown, and Kochel (2009), Spera and Wentzel (2003), Wentzel (2005b), and Wentzel and Brophy (2014). These studies emphasise the important role that different goal orientations and the role peer and students can play in the enhancement of students' motivation.

All the above-mentioned findings and explanations about the impact of CCCM on students' motivation towards science learning suggest the possibility that CCCM essentially motivated Indian secondary school students to learn conceptually. These findings of the thesis not only add to the current concept mapping and science education literature but also add to the motivation and *motivation to learn* literature and offer possibilities for further research to explore this effectiveness in more detail and in different contexts.

5.3. Students' and teachers' views of CCCM use

The third research question of the study was to explore participant science teachers' and students' perceptions and experiences of CCCM use in their classrooms. This section provides a discussion of these perceptions and experiences in relation to the impact of these perceptions on teaching and learning in the science classrooms. The interview findings from both the teachers and students, as presented in the previous chapter, revealed a positive attitude towards CCCM use in secondary science teaching and learning. The participant teachers as well as students believed that CCCM could encourage students to collaborate, improve relationships, discuss content and ultimately could enhance conceptual learning. The discussion of students' and teachers' views of

CCCM use is presented around the four main themes obtained from re-arranging and combining similar themes out of the nine themes that emerged from teachers' and students' interviews (section 4.4). The following diagram (Figure 5.1) displays the four key themes for the discussion presented in the following sub-sections about CCCM use in secondary science teaching and learning.

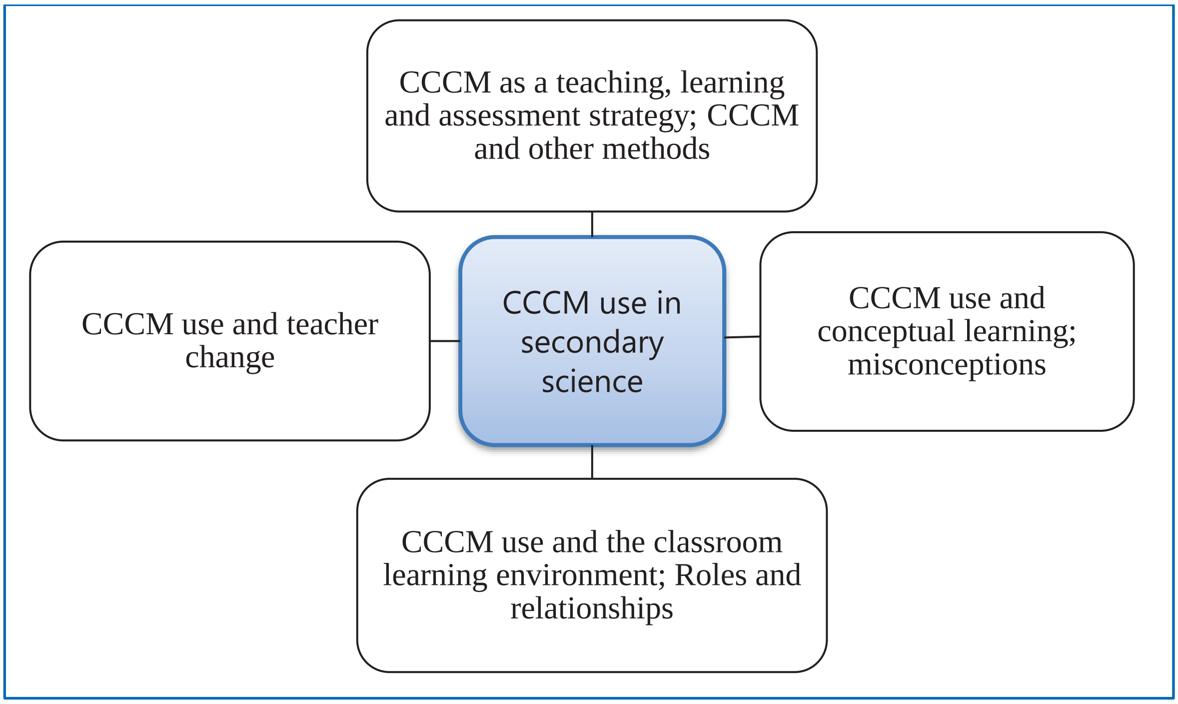


Figure 5.1 Teachers' and students' views of CCCM use in secondary science

5.3.1. CCCM as a teaching, learning and assessment strategy

The findings presented in the previous chapter 4 (sections 4.4 and 4.5) suggest that both teachers and students perceived the CCCM intervention to be useful in science learning for secondary students. Although both participating teachers reported that they were unaware of the concept mapping strategy before participating in this study, they had previously used other strategies (e.g. project work and group work) in their classrooms. The results from the teachers' and students' experiences of using CCCM suggested that CCCM is beneficial in supporting teachers to adopt and implement a *participatory active pedagogy* (National Council of Educational Research and Training, 2005) to facilitate teachers' teaching and students' science learning. Students also echoed the positive attitude shown by teachers towards CCCM use to enhance their learning.

Concept mapping has been reported as an effective teaching and learning strategy to enhance students' meaningful learning (Buntting, 2006; Kinchin, 2000), to assess conceptual understanding (Novak, 2010, 2015), to make students' understanding visible (Kinchin et al., 2000) and to promote collaboration among students (Adesope & Nesbit, 2010). In this way, the use of CCCM in secondary science can be considered not only as a teaching and learning strategy but also an assessment *tool*. Although, assessment is not the focus of this thesis, it became clear during the qualitative data analysis that the participant teachers considered concept mapping suitable for assessment.

The participant teachers used concept mapping as both a formative and a summative assessment tool. It is important to remember that in the Indian school context, students and teachers still consider assessment as a separate entity to teaching and learning, which is contrary to the recent views of researchers such as Black and Wiliam (2012), Dylan (2008) and, Havnes, Smith, Dysthe, and Ludvigsen (2012). These modern investigators consider assessment as a conjoint and integral part of instruction/teaching. The role of CCCM as an assessment tool is worth discussing and promoting in the Indian context in which there is much focus on developing more and alternative methods of formative assessment. The use of CCCM as an assessment tool is in line with the findings reported by other researchers such as Beaudry and Wilson (2010), Buntting (2006) and Vodovozov and Raud (2015). However, this thesis presents a different aspect of the use of concept mapping as an assessment tool, which is assessment of students' lower-order cognitive skills (LOCS) and higher-order cognitive skills (HOCS), and which is in contrast with many of the research studies available in the concept mapping literature at the school stage. In that direction, this thesis proposes CCCM as an alternative method of assessment to make the assessment part of teaching more student friendly, assessing deep/meaningful learning, making students' thinking visible and ultimately informing teachers' instruction.

In relation to promotion of effective learning, students and teachers specifically mentioned that CCCM can help students to plan and organise their learning, prepare quick notes and, revise and reflect on their learning. Teachers also reported CCCM as useful in supporting them to examine students' prior knowledge which in turn can help in planning instruction and providing feedback to facilitate and enhance students' learning. Some of these views are consistent with findings from research carried out by Buntting (2006), Chako (2009) and Dhaaka (2012). However, the collaborative aspect of the CCCM is new to the Indian context where collaboration is being explicitly stressed (National Council of Educational Research and Training, 2005, 2006) after recognising the shortcomings of promoting competition among students. Therefore, this thesis proposes CCCM use as a platform to promote collaboration among students where students contribute to and support their peers' learning. This novel use of CCCM is worth considering in the Indian science education context where there is a lot of stress on competition. Moreover, the concept of collaborative learning using CCCM is very similar to the *Computer-Supported Collaborative Learning* (CSCL), proposed by Stahl et al. (2014) and which, according to the authors is an *emerging* branch of the learning sciences and is focussed on understanding the process of learning using computers in collaborative situations.

In this way CCCM use seems to fit with the pedagogy of constructivism. This pedagogy explicitly focus on students' prior knowledge, collaboration and scaffolding, representation of mental models, making thinking visible and developing of students' 'visual literacy' and 'meta-visual capability' (Gilbert, 2005, 2008). Gilbert (2008), for example, has stressed an optimum use of visualisations (such as knowledge organisers, concept and mind maps) arguing that visualisations help students assimilate diverse types of information and if integrated with the text, can make the learning process easy and ultimately can enhance meaningful learning and conceptual understanding (Gilbert, 2015). Moreover, CCCM as a visualisation - which is a systematic and focussed display of information - has been repeatedly reported in science learning literature as very useful (Adesope & Nesbit, 2010; Nesbit & Adesope, 2006; Novak, 2010).

In the broader context of science education, another interpretation of the interview findings suggests that CCCM can help in the development of argumentation and thinking skills as proposed by Khine (2015), Kuhn (2015a) and Osborne (2012), and promotion of productive *educational dialogues* (Howe, 2010; Mercer & Howe, 2012; Mercer & Littleton, 2007). The CCCM intervention also has the potential to address the challenges associated with the assessment of these 21st century skills (see Osborne (2013) and OECD (2013a, 2013b) for more details). The skills of collaborative learning, communication, effective use of ICT, problem solving and divergent thinking, are stressed and focussed in the contemporary science education literature. This use of CCCM as an assessment strategy is additionally useful in light of the demands placed by PISA, TIMSS and NAEP which all seek "to assess more than content knowledge"

(Osborne, 2013, p. 267). For instance, PISA 2015 intends to assess procedural and epistemic knowledge and its application in everyday contexts along with factual content knowledge. CCCM can potentially be used for the assessment of cognitive, intrapersonal, and interpersonal competencies as described by the National Research Council (2012a) and the *New K-12 Science Standards* (National Research Council, 2012b). Moreover, CCCM also can be used to promote and assess the Collaborative Problem Solving (CPS) competency, which according to OECD (2013a) is "the capacity of an individual to effectively engage in a process whereby two or more agents attempt to solve a problem by sharing the understanding and effort required to come to a solution and pooling their knowledge, skills and efforts to reach that solution" (p. 6). This CPS competency represents a combination of collaborative skills and problem solving skills, collaboration being the major dimension (OECD, 2013a) and is a focus of the recent PISA 2015 assessment.

Both students and teachers reported CCCM as a better and preferred method of teaching and learning science over the traditional didactic lecture methods. Their reflections of the experiences of using CCCM seemed consistent with the enhanced results for conceptual learning and motivation towards science learning. Students and teachers stated that enhanced interaction, communication, relationships, autonomy and freedom were some of the reasons for their preference for the intervention over other methods. As speculated in section 5.1.3, there could be many factors behind this preference of CCCM over other methods of teaching and learning, such as the novelty effect and a change in the classroom environment. Whatever is the reason, the majority of the students and both the teachers reported using CCCM in other subjects and classrooms. The preference for using concept mapping in science learning over other teaching-learning strategies such as lecturing, writing summaries, outlining and group discussion is consistent with previous research by Adesope and Nesbit (2010), and Nesbit and Adesope (2006).

5.3.2. CCCM and conceptual learning

Teachers' interview findings and students' focus group discussion findings suggested that they believed CCCM could enhance secondary students' conceptual learning by facilitating students' interaction with the curricular content, helping students link the major and minor concepts, discussing with peers on the topic given and finding and addressing students' faulty conceptions and knowledge gaps. Students also reported that CCCM helped them to learn how to think and integrate different types of thinking, and to help understand different concepts of science curriculum. In this way, CCCM seemed effective in promoting conceptual learning among secondary students, including helping them to identify their misconceptions and correct them.

To promote conceptual learning, CCCM appeared to provide a platform to collaborate with peers which allowed students to think together, argue and agree and disagree. In doing so, CCCM can not only promote *conceptual change*, but also *conceptual exchange*, the two different aspects described by Hewson (1992, June). Hewson explicitly points out the need to develop appropriate strategies to elicit students' existing conceptions and teach them accordingly to facilitate their learning. Hewson (1992, June) further argues that all conceptual change (exchange and extension as he proposes) happens in a social milieu and explicitly depends on individual's cognitive structure influenced by social interactions. From this point of view, the collaborative learning environment created by CCCM and findings related to its impact on students' conceptual learning (sections 4.2 and 4.4.3) suggest that CCCM facilitates an understanding of science concepts. Moreover, concept mapping has been frequently reported as an effective strategy to elicit students' initial understanding, facilitate conceptual learning and to reveal understandings at the final stages of learning (Kern & Crippen, 2008; Konicek-Moran & Keeley, 2015). Consistent with the *thinking together* framework by Littleton and Mercer (2013) and Mercer and Littleton (2007), this research demonstrates the importance of a dialogic method and productive talk to promote secondary students' collective thinking and conceptual learning.

There are many research studies such as Mintzes et al. (2000), Dougherty, Custer, and Dixon (2012), and Soika and Reiska (2014) which have assessed students' conceptual learning using concept mapping. However, there are very few which have explicitly investigated its impact on LOCS and HOCS (Bramwell-Lalor & Rainford, 2013). This research has tried to assess the process of conceptual understanding similar to the *HOCS* framework proposed by Zoller and Nahum (2012). The Zoller and Nahum (2012) *HOCS* framework places the cognitive processes of critical thinking, system thinking, problem solving, application and transfer of learning, reflection and self-regulation at the core of any learning activity to promote *learning to think* in science classrooms. The focus on HOCS based on Anderson and Krathwohl's (2001) revised Bloom's taxonomy in the design and implementation of the achievement test ATS9 (appendix H) in this research is also consistent with recommendations from Zoller and Nahum's (2012) *HOCS* framework. The findings from this research have potential to contribute to promote HOCS-related competencies/capabilities, not only in the Indian context but also in the international concept mapping and science education literature.

It is again important to remind the reader that the focus of this study was on conceptual learning and not the identification and correction of misconceptions. Although, misconceptions need to be identified and corrected before teaching (Taber, 2015) to advance deeper conceptual learning, the process was considered conjoint of the broader concept of *conceptual understanding*. There is an extensive body of research that reports on the alternative conceptions and misconceptions in science and its constituent subjects. However, the teacher interview findings (section 4.4.3) suggested that CCCM could identify and correct misconceptions by making the relationships between concepts visible and analysing them. In this way CCCM could be used as a diagnostic assessment tool to identify alternative conceptions and misconceptions and help students to change them to the conceptions which are more consistent with consensual scientific views (Buntting et al., 2006).

In this way, the current research adds to the wider context calling for design of pedagogical interventions which could motivate students to learn, and that promote the development of deep conceptual understanding of difficult and abstract science concepts at the secondary school stage. In the Indian context, design and development of effective instructional strategies and implementation of the *teaching for conceptual understanding in science* framework (Konicek-Moran & Keeley, 2015) is suggested for enhancing students' conceptual learning and motivation towards science learning (National Council of Educational Research and Training, 2005, 2006).

5.3.3. CCCM and classroom learning environments

Findings from the teacher interviews (section 4.4.5) and students' focus group discussions (section 4.5.3) suggested that CCCM has the potential to facilitate constructivist learning environments in Indian science classrooms. Teachers and most students stated that CCCM created an interactive and encouraging learning environment by improving relationships, communication, attitudes, interest and shifted the focus from rote learning to conceptual understanding. Both teachers and students perceived the role of the teacher as a facilitator of discussion and as a facilitator in creating conditions for conceptual learning in their classrooms. Such findings are in line with recent constructivist views of learning in the science education literature such as Littleton and Mercer (2013), and Tobin (2012). In addition, the findings revealed that CCCM has the potential to improve peer and student-teacher relationships and make students feel more confident and comfortable to approach the teacher. However, consistent with the findings from Greenwood (2002), some students reported contrasting views to what their teacher stated in relation to providing ample freedom and autonomy in the class. Suggestions made by these students have implications for further design and implementation of such interventions.

Overall, CCCM use appeared to promote constructivist learning environments which emphasize and facilitate student cohesiveness, teacher support, good teacher-student and peer relationships, collaboration, student autonomy and active learning strategies as suggested by Fraser (2012) and Doll, Spies, LeClair, Kurien, and Foley (2010). In contrast with most of the classroom environment surveys and scales, this study has focussed and investigated dimensions of classroom learning environments very similar to the Doll et al. (2010) study. These dimensions as outlined above are: relationships; student-teacher and peer relationships; teachers' role, support and feedback; students' perceived competencies such as self-efficacy, self-determination; and classroom support to develop all of the above-mentioned competencies in students.

5.3.4. CCCM and teacher change

Both teachers reported many changes not only in their beliefs about learning and teaching, but also in relation to their practices as a result of CCCM use in their classrooms. The two science teachers perceived a shift in their roles from being transmitters of information to facilitators of students' learning and discussions. Teachers mentioned that the CCCM use had enriched their practices, adding some important strategies such as collaborative learning, assessment for learning and providing detailed and timely feedback. One of the teachers reported a substantial improvement and change in her attitude and behaviour in the class. She stated changing from being more authoritative and controlling to providing more student autonomy and freedom to carry out learning activities. Findings from the student focus group discussion also confirmed and echoed the changes mentioned by the participating teachers. Students reported the teachers as being friendlier, caring, supportive, motivating and displaying more positive attitudes as a result of CCCM use in their classrooms.

Consistent with findings from studies such as Huan (2014) and Guskey (2002) regarding change in teachers' beliefs and practices, findings from the current study suggest that CCCM has the potential to promote teacher change in science classrooms. However, both the teachers in the current study, reported the process as easy, interesting and enriching (section 4.4.5), in contrast to the *difficult* process often reported for teacher change process (learning of new practices), for example, Davis (2003).. The research is timely, given that a change towards adoption of more participatory, active and constructivist pedagogies is explicitly focussed on in the Indian National Curriculum Framework 2005 (National Council of Educational Research and Training, 2005). Therefore, the findings of the current study highlight the potential advantages of changes in teachers' practices to facilitate and promote students' learning and motivation in the Indian context where traditional pedagogies continue dominate in the science classrooms.

5.4. Enablers and barriers to CCCM use in Indian classrooms

The fourth research question of the study was to identify enablers and barriers to the use of CCCM in Indian secondary school science classrooms. A range of enablers and barriers were highlighted by teachers and students based on their perceptions and experiences of CCCM use in their classrooms. The major factors identified as providing support or hindering the use of CCCM are organised and presented in the result chapter as related to the teacher, students and school (see sections 4.4.7, 4.4.8, and 4.5.4). Here, a joint discussion of students' and teachers' perspectives is presented in the two categories of enablers and barriers to the CCCM use in the following two sub-sections.

5.4.1. Enablers to the CCCM use

Among teacher-related factors that could support the implementation of CCCM intervention, the two science teachers reported factors such as expertise, attitude of teachers towards change, awareness of and expertise in using different instructional strategies, familiarity with concept mapping and the concept mapping software, patience and pace of the teacher, provision of timely and constant students' feedback, and a friendly and encouraging attitude. Teachers also identified teachers' knowledge of students' beliefs and conceptions, prior knowledge, and use of students' conceptions as resources in teaching to facilitate students' learning. The use of the conceptions/alternative conceptions as resources in the classroom is in line with the argument extended by Hewson (1992, June) who argues:

> We need to recognize that "alternative" is not a synonym for "inadequate" or "unacceptable". The purpose of conceptual change teaching of science is not to force students to surrender their alternative concepts to the teacher's or scientist's conceptions but, rather, to help students both form the habit of challenging one idea with another, and develop appropriate strategies for having alternative conceptions compete with one another for acceptance. (p. 9)

Therefore, teachers can use misconceptions held by students as resources to initiate and extend discussions in their classrooms rather than considering them as unwanted and unhelpful. These observations made by the science teachers have implications for prospective and in-service teachers in relation to utilising students' alternative/naïve/faulty/wrong conceptions in their classrooms to facilitate educational dialogue and productive talk.

Students identified similar teacher-related factors that could enable CCCM use and that had been outlined by teachers in their interviews, for example, the important role played by teachers to encourage CCCM use and the support provided during the actual use in their classrooms. Students highlighted the importance of the help and feedback from their teacher. A friendly and motivating attitude of the teacher, the pace of the lesson and patience on the part of the teacher were some other factors mentioned. Some researchers, such as Wentzel (2009), Good and Brophy (2008) and Woolfolk (2014), place emphasis on the encouragement and constant support provided by teacher to students. In relation to student-related enablers, teachers identified students' interests, positive attitudes towards the intervention, and their motivation, perceptions and past experiences as enablers to the use of CCCM. Teachers also mentioned that students' persistence and their understanding of the concepts and their relationships could promote CCCM use. Consistent with the research by Wentzel (2005b), and Wentzel and

Watkins (2002), students also highlighted the important role played by peer support and mentioned that the relationships among students in the group- responsibility, trust, collaborative efforts and positive attitude towards learning of the group members - could significantly affect CCCM use in their classrooms. However, some students made suggestions about the need to improve the peer and student-teacher relationships based on their experiences. These suggestions have implications for making the use of similar interventions more effective and student friendly.

Teachers also highlighted many school-related factors that could enable CCCM use in the intervention classrooms. Some major enablers mentioned were: the attitude of and support from the school head and ICT instructor and infrastructure such as computers, software and internet. While most of the students seemed unaware of school-related factors, some highlighted the role that the internet could play to make CCCM use more effective. All these enablers, as stated earlier, have implications for the future use of CCCM and similar interventions in similar or different educational contexts.

5.4.2. Barriers to CCCM use

Many factors that could impede the use of CCCM in the Indian science classrooms were highlighted by science teachers and students. Amongst teacher-related barriers, the participant teachers mentioned teachers' negative and suspicious attitudes about the intervention, lack of confidence and experience in trying innovations in the classroom, teachers' lack of sound content knowledge and lack of knowledge about students' beliefs and prior understandings. The participant teachers also identified teachers' lack of knowledge about different instructional strategies and classroom management strategies as barriers to CCCM use in their classrooms. Similarly, students highlighted some teacher-related barriers such as lack of an appreciative attitude towards students' work, lack of expertise in software handling, the pace of the lessons, and time and class management skills.

Amongst student-related barriers, teachers mentioned students' understanding of the basic science concepts and their relationships, understanding of the importance of CCCM use, as well as interest and motivation to use the new method for learning science. Students put emphasis on peer relationships and support and stated that a lack thereof could significantly affect the collaborative learning and hence the use of CCCM. Students also highlighted the time and effort students put in, interest, motivation and attitudes towards group work highlighting, that a lack of these could negatively impact the use of CCCM. The group structure and composition (number of students, gender) and not following the agreed/established group norms were also reported as barriers that could negatively impact the use of CCCM in secondary science classrooms.

Science teachers and students also mentioned some school-related barriers that could affect CCCM use. Teachers put emphasis on the lack of a positive attitude and support from the school principal and ICT instructor as major impeding factors. Insufficient computers and unavailability of software were other factors mentioned by teachers. Availability of the computer lab was mentioned as one of the factors that could negatively impact CCCM use. Large class size was also identified as a factor that could hamper the effective use of the CCCM intervention. Surprisingly and contrary to researcher's expectation of small class size in such a well-planned and major Indian city, the class sizes of the intervention groups (57 and 67) and control groups (55 and 62) were found to be large. The large class size can and surely have implications about the findings related with the effective CCCM use in secondary science classrooms. In such situations of crowded classrooms, implications of this research have potential to offer some solutions to the classroom management and application of collaborative learning instructional strategies. This aspect is discussed in more detail in the next chapter. Similar factors, such as lack of positive attitudes and availability of the computer lab, were also highlighted by students. All these supports for and barriers to the CCCM use offer some important implications (section 6.3) for the design and implementation of similar interventions in similar and different contexts.

This chapter discussed the qualitative and quantitative findings of this study in relation to the literature from Indian and international contexts. The discussion was presented according to the four research questions of the study. The impact of the intervention on students' conceptual learning and motivation towards science learning appeared to be promising to address the learning crisis highlighted by Banerji (2012, 2014) and Ramachandran (2015), and envisioned by the Indian National Curriculum Framework 2005 (National Council of Educational Research and Training, 2005). Findings from the teacher interviews and students' focus group discussions also suggested a positive impact of CCCM use on enhancing students' conceptual learning, motivation towards science learning and in creating constructivist learning environment in Indian classrooms. The enablers and barriers to the CCCM use were also discussed. The conclusion of the study along with limitations, implications and recommendations are the subject matter of the following chapter.

Chapter Six. Conclusions and Implications

The previous chapter presented a detailed discussion of the findings in the Indian and wider international science education contexts. Some indications of the potential and significance of the findings were also made in terms of the research intent. This chapter presents the final conclusions and implications reached. The aims of the research are revisited/ reviewed and are examined in terms of the degree to which the research questions have been answered. The significance and implications of the findings are discussed in the Indian as well as in the broader contexts. A further section focuses on the contribution to knowledge in the field of science education. The section also presents the conceptual learning framework which resulted from the research. Methodological constraints and limitations of the research are considered. Finally, some reflexive comments are added at the end of the chapter.

6.1. Conclusions from the study

The main aim of this study was to investigate the effectiveness of the educational intervention: Computer-based collaborative concept mapping (CCCM) in Indian secondary school science classrooms. Inherent in this aim were the objectives to design, develop and implement the CCCM intervention, and investigate (to evaluate) the effects of CCCM on secondary school students' science achievement, conceptual learning and motivation towards science learning. The study also examined students' and teachers' perceptions and experiences of CCCM use in their classrooms. Additionally, the enablers and barriers to CCCM use were also investigated and reported. The following sections present information about the degree of achievement of these specific objectives and general aims of the study.

The CCCM intervention was designed and developed by integrating three instructional strategies- computer-based learning, collaborative learning, and concept mapping- and was based on the meaningful learning framework and the motivation to learn framework. Both the learning and motivation frameworks were based on the social constructivist (social-cognitive and sociocultural) theories. CCCM was then implemented in the intervention classrooms to achieve the specific objectives of this research. The study, through its first two research questions, sought to investigate the effects of CCCM on secondary school students' science achievement, conceptual learning and motivation towards science learning. The results obtained for the first two research questions, which utilised mixed methods of data collection, were presented and discussed in chapter 4. The findings from the achievement test ATS9 suggested that CCCM use could enhance conceptual learning as well as the overall science achievement of Indian secondary school students. The comparisons and analyses of the individual and group learning samples (ATS9 responses and some focussed group concept maps) also indicated enhancement of higher-order cognitive skills (HOCS), lower-order cognitive skills (LOCS) and thus conceptual learning in science. The results from the motivation questionnaire SMTSL and from teachers' and students' interviews also indicated an overall enhancement of secondary school students' motivation towards science learning as a result of CCCM use.

Through the third research question, the study sought to explore students' and teachers' perceptions and experiences of CCCM use in their classrooms. Students and teachers showed mostly positive attitudes towards CCCM use and believed that the intervention enhanced science learning and teaching. In addition to the use of CCCM as a teaching and learning strategy, teachers reported that CCCM could also prove to be a better assessment strategy than the traditional assessment tools available to them. Although, assessment is usually seen as intertwined with teaching and learning, as mentioned in the discussion chapter, in the Indian education context assessment is seen as separate entity. Teachers and students also believed that CCCM use could enhance students' conceptual learning by addressing misconceptions. Students and teachers pointed out that CCCM use could help in designing their classrooms as constructivist learning environments by improving relationships, roles and responsibilities among students and teachers. Teachers also thought that CCCM use could positively affect teachers' beliefs and practices.

Finally, the research explored some enablers and barriers to CCCM use in the selected Indian science classrooms. Findings from teachers' and students' interviews included a range of factors that could either support or impede CCCM use. Three types of enablers and barriers were identified. These were: teacher-related, student-related and school-related factors. Some of the main factors identified were the knowledge and expertise of the science teacher, teacher and student motivation and interest to use innovative strategies, teacher knowledge of students' prior conceptions, peer-support and teacher-student relationships and interactions. Some of the school-related factors identified were: attitudes of the head of the school toward innovations, infrastructure such as computers, software and resources, and the class size. An additional factor, although not articulated previously in the findings but observed by the researcher, was the level of trust from head of a school in research and researchers.

In short, the CCCM use appeared to be effective in enhancing Indian secondary school students' conceptual learning and science achievement. The use of CCCM also enhanced the overall motivation of the participating Indian secondary school students towards science learning. Both students and teachers showed mostly positive attitudes and reported CCCM as a preferred method of teaching and learning over traditional didactic lecture methods. Some enablers and barriers were identified to inform future uses of CCCM or similar interventions in similar or different contexts.

6.2. Significance of the research

This research is significant in many aspects, some of which were serendipitous and not identified at the beginning of the research. First of all, the research is timely with the explicit focus on the development of 21st century skills (for example, collaboration, communication and ICT) placed by many ministries and the new Government of India through various schemes such as Pradhan Mantri Kaushal Vikas Yojana[18] (PMKVY), and the launch of the "National Skill Development Mission" and "Skilled India" Mission. The skills of effective collaboration, cognitive skills (LOCS and HOCS), communication, socio-relational, emotional and ICT skills are some of the broad spectrum of intended skills, of which development and improvement was the central, although implicit, focus of this research.

The Indian Government is investing large amounts of money to develop the skills of Indian youth and is committed to achieving the vision of "Skill India" and to make India the "Skilled Capital of the World" (Ministry of Skill Development and Entrepreneurship, 2015). Moreover, many other governments (e.g., Australia, Singapore,

[18] English translation: Prime Minister's Skill Development Plan

USA, Costa Rica, Netherlands and Finland) and private corporations worldwide (such as, Cisco, Intel and Microsoft) are making provisions to teach, develop and assess *21st Century Skills* (Griffin, Care, & McGaw, 2012). As a result of this worldwide collaboration between government institutions and corporations, 21st Century skills are explicitly defined and explained through the ATC21S™[19] framework (Griffin & Care, 2015). The ATC21S™ framework describes ten 21st century skills in terms of four broad categories: ways of thinking, ways of working, tools for working, and ways of living in the world. For more details the reader is advised to refer to Binkley et al. (2012). Therefore, consistent with the ATC21S™ executive board's research (see http://www.atc21s.org for details), the research detailed in this thesis can play an important role by proposing CCCM use as a teaching and learning strategy in relation to the development of these 21st century skills.

Secondly, the research is significant in the Indian context as it addresses and offers some potential solutions to the prevailing learning crisis in the Indian secondary school classrooms (Banerji, 2014; Pritchett, 2015; Ramachandran, 2015). The research findings suggest implementation of participatory and active learning strategies, such as CCCM, as envisioned by the Indian National Curriculum Framework (National Council of Educational Research and Training, 2005). The research is also important in starting a debate around the cognitive, affective and socio-relational dimensions of collaborative learning and its impact and use at secondary school stage of schooling. The *motivation to learn* science construct of general motivation is recent and specific, and has never been researched in the Indian context. This research therefore adds some vital pieces to the jigsaw of conceptual learning and motivation in secondary school science. Some of the following points outline other important aspects of this research:

1. This study is the first of its kind in an Indian context, which has designed and investigated the effectiveness of an intervention on students' *motivation to learn* construct in science as defined and proposed by Brophy (2010b) and, Wentzel and Brophy (2014). Very few similar studies have been reported at the international level.

[19] The acronym ATC21S™ is a globally trademarked that stands for the Assessment and Teaching of 21st Century Skills

2. This study is the first of its kind in the Indian context, which has applied the design-based research (DBR) methodology to design an intervention with the aim of enhancing conceptual learning and motivation to learn science.

3. Findings from this study suggest the potential to promote learner-centred, interactive, active and participatory pedagogy in the Indian secondary school contexts through the use of CCCM in order to motivate secondary school students to understand science.

4. While many studies have examined the effectiveness of concept mapping (CM), collaborative concept mapping (CCM) and computer-based concept mapping (CBCM) separately, there is little research investigating the effectiveness of computer-based collaborative concept mapping (CCCM) on conceptual learning of secondary school students, and no published study has been conducted in the Indian secondary school science (or Indian science education) context using such or similar intervention.

5. Very few studies have researched conceptual learning at secondary school stage from the revised Bloom's *taxonomy for learning, teaching, and assessing* (Anderson & Krathwohl, 2001) perspective in India. Further, very few have investigated the factual, conceptual and procedural dimensions of knowledge and development of LOCS and HOCS in the Indian science education context. Once again, this study is the first of its kind to explore these aspects and issues in the Indian science education context.

6. Keeping in mind the important benefits of the ICT use in education (Jonassen, 2000; Jonassen et al., 2008; Kwan, Fox, Chan, & Tsang, 2008), this study integrated ICT with effective pedagogy as recommended by *the New Science of Learning* (Sawyer, 2014a) to design an intervention that appears to be enhancing students' conceptual learning and motivation. The intervention can be used in face-to-face mode of learning and teaching to enhance students' learning and motivation.

6.3. Implications for practice

Given the fact that this research is based in Indian secondary classrooms, most of the implications it offers will obviously address issues at a classroom level. The study offers some important implications for students, teachers, school heads, professional development providers, curriculum designers and other stakeholders involved with the planning, execution and evaluation of students' learning and motivation. Following are the major implications from the research:

1. Through the designed intervention this study intended to improve Indian secondary students' learning and motivation, an implicit aim was to develop the 21st century skills of effective collaboration, ICT use, problem solving, critical thinking, cognitive and affective skills. These skills are outlined, stressed and envisioned, through recent reports, by national and international agencies such as NCERT, MHRD, OECD and PISA.
2. This research proposes an innovative and research-based teaching-learning-assessment strategy not only to enhance students' conceptual learning and achievement but also to boost their motivation towards science learning as well as to monitor students' learning progress.
3. Findings of this study suggest that the CCCM intervention can provide a change in the traditional classroom learning environment by providing a platform to discuss, debate, argue, and finally learn and understand science.
4. The findings regarding the implementation and evaluation of the intervention used in the research suggest that CCCM can offer an additional strategy to equip the science teacher, who can utilise it to facilitate student learning especially in the crowded Indian science classrooms.
5. For classroom teachers, the study incidentally also offers the use of CCCM as a tool for the formative, summative or alternative (individual and collaborative) assessment of students' learning. This, additionally, is an implication for curriculum designers and examination boards to take into account when designing and suggesting methods to assess learning.
6. Professional development (PD) providers can use the CCCM intervention to train science teachers and to develop their skills and knowledge about active, participatory and student-centred pedagogies.

7. School principals need to show welcoming and positive attitudes towards innovation and change. They are expected to encourage teachers to adopt evidence-based strategies and interventions such as those recommended by national and international researchers.
8. Curriculum designers can introduce and recommend such interventions for the benefit of students and teachers. They can also provide some examples of such studies/case studies to encourage teachers to design, develop and use this kind of intervention.

6.4. Contribution to knowledge

This research, being unique in the Indian context, adds to the literature on the design, development and evaluation of learning and motivation interventions in Indian schools. The original contribution of the study is the design, implementation and evaluation of the CCCM intervention consistent with the emphasis placed by the INCF 2005 (National Council of Educational Research and Training, 2005) on the development of active, participatory and learner-centred pedagogies. This study adds many important pieces (aspects) to the puzzle of teaching-learning-assessment in the classroom. Learning and motivation were researched from different perspectives to those usually used in the field of science education. The process of conceptual learning was researched in terms of LOCS and HOCS, and the social-cognitive aspect of motivation was explored and made explicit in this research. In addition to adding to the teaching, learning and assessment aspects of science education in India, this research also adds different dimensions to the broader fields of concept mapping and motivation in science education. Moreover, this research also adds another exemplar to the design-based research (DBR) methodology literature in science education specific to the Indian context.

Although there is a considerable amount of research on concept mapping at different levels of schooling, higher, professional and technical education in India, very few studies have implemented collaborative concept mapping and computer-based concept mapping in the Indian context. No study to date has been reported investigating the effect of CCCM or similar learning interventions in secondary school science education. This study is the first of its kind to design, implement, and examine the effectiveness of such a learning intervention (CCCM) on secondary school students' conceptual learning and motivation towards science learning in India. Furthermore, there is hardly any research carried out in the Indian context to investigate the effectiveness of concept mapping or a concept mapping-based intervention either on LOCS and HOCS, or on the four categories of students' knowledge from Bloom's revised taxonomy point of view (L. W. Anderson & Krathwohl, 2001; Krathwohl, 2002). From this perspective, this research also makes an original contribution in terms of the Indian as well as the international contexts. In the Indian secondary school context, findings from this study suggest that the CCCM intervention can play an important role in motivating secondary students (aged 14-17) to learn conceptually, where learning by rote and other traditional methods dominates and the nature of the science concepts changes from the concrete to abstract.

Based on the findings of this study, it appears that CCCM has potential not only to encourage students to collaborate and learn science conceptually but also to encourage science teachers to re-think their pedagogies/teaching practices and transform them by adopting and implementing more contemporary evidence-based and learner-centred pedagogies as envisioned by the Indian National Curriculum Framework (National Council of Educational Research and Training, 2005). Further, concept mapping meets the conditions for conceptual learning as proposed by Ausubel (2000) in terms of presenting the science content clearly and in relation to the prior knowledge of students so that students can relate the new information prior to instruction and revise and refine their conceptual understanding accordingly (Konicek-Moran & Keeley, 2015).

Some Indian researchers, for example Kharatmal and Nagarjuna (2006, 2009), propose to refine and introduce rigor (Kharatmal & Nagarjuna, 2010) in concept maps to add to their effectiveness and to reduce the expert-novice difference in knowledge structures. This thesis however, proposes a different aspect and dimension which increases the rigor of concept mapping, thus making another additional contribution to the concept mapping research and knowledge. This thesis formulates a proposal for deeply examining the process aspect of conceptual learning during CCCM to understand what actually goes on in the group. Students' individual as well as group learning can be explored and monitored using CCCM. This research also propose to assess students' science conceptual understanding qualitatively according to the criteria developed in this thesis (appendix L) rather than quantitatively assessing the concept maps as suggested by researchers such as West, Park, Pomeroy, and Sandoval (2002); Rye and Rubba (2002), and Yin, Vanides, Ruiz-Primo, Ayala and Shavelson (2005). Furthermore, consistent with the design principles aspect of DBR (sections 3.3.1-3.3.2) this research contributes a framework/model for motivating secondary school students to learn science conceptually. The model emerged from this research is presented in the following section 6.4.1.

6.4.1. A framework for conceptual learning in science

In addition to the earlier mentioned contribution of this study, and keeping in mind the promising results of improved students' learning and motivation, the following framework for *Conceptual Learning at Secondary*[20] *Stage of Science* (CLASS of Science) is proposed. This framework is a direct result of the findings and the DBR procedure carried out during this research. Moreover, as Bakker and van Eerde (2015) state, "theory typically has a more central role in DBR" and one of the important functions of any DBR study is "*to develop theories about learning and the means* [interventions, products] *that are designed to support that learning*" (p. 437; emphasis added). The current study utilised this characteristic of the DBR methodology and henceforth proposes the following framework to advance conceptual understanding of science at secondary school level.

As shown in the Figure 6.1, the framework places the motivated learning intervention CCCM at the centre of the model. The CCCM intervention, as shown in the figure, is broadly a result of the integration of three strategies: computer-based learning, collaborative learning, and concept mapping. These three strategies are shown as the base of the CCCM in Figure 6.1. The collaborative learning strategy, as depicted in the figure is larger than computer-based and concept mapping because it constitutes the core of the CCCM intervention and has further associated dimensions and processes which need to be addressed while implementing it in a specific classroom context (learning environment). For example, the processes of mutual support, care, relationships and trust on the part of students, which were implicit in the design, but were focussed and made explicit while implementing the intervention. These cognitive,

[20] As mentioned in section 1.2.1 of Chapter 1, in the Indian context, grades 9 and 10 form the secondary stage of schooling. Findings reported in this study are based on data from grade 9 only.

affective and relational dimensions (aspects) of the collaboration in science learning are assumed to be supporting collaborative learning. The development as well as the balance of these dimensions of collaborative learning during the CCCM intervention is suggested to inform the effectiveness of CCCM intervention.

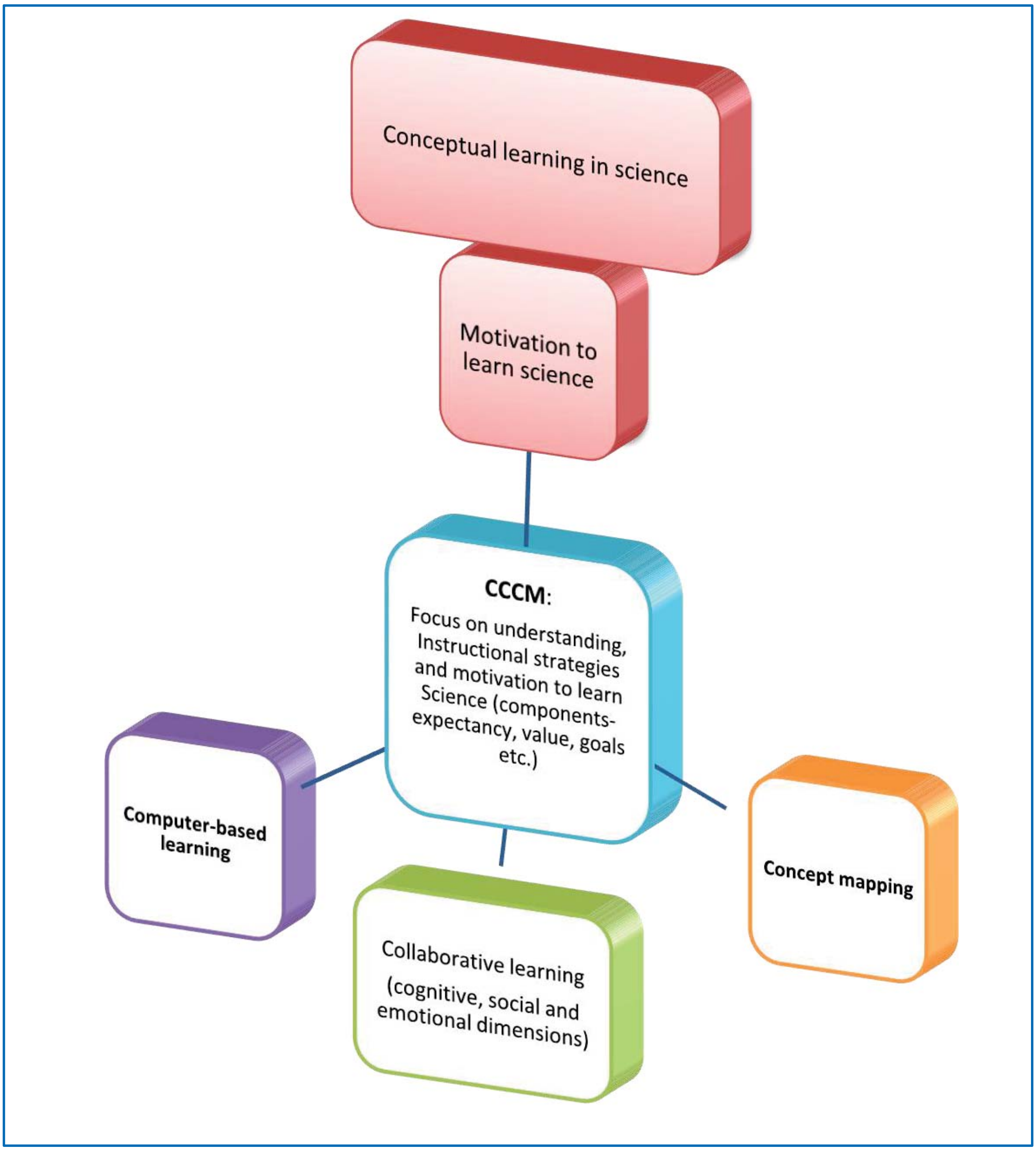


Figure 6.1 A Framework for Conceptual Learning at Secondary Stage of Science

During the implementation phase of CCCM, the main focus is placed on the understanding of science concepts. This aim of understanding can be achieved through the application of some specific instructional strategies as mentioned in the design of the CCCM intervention (section 2.7). Moreover, the explicit emphasis placed on the motivation (and motivation to learn science) components, for example self-efficacy, value of science and, learning and performance goals in the intervention design, can facilitate achieving of the major goal of motivating secondary students to learn science.

The intervention design and focus on motivational components may also help to develop the self-beliefs, competence, confidence and social (peer and student-teacher) relationships (Wentzel, 2005a, 2005b, 2009; Wentzel et al., 2014), which may help to satisfy students' autonomy, competence and relatedness needs in their classrooms. Given the focus of the intervention on understanding of scientific concepts and on the development of cognitive, social and emotional dimensions of learning, this may lead to an improved motivation towards science learning as proposed by this thesis and shown in Figure 6.1. Because, the *motivation to learn* aspect emphasizes students' tendency to value learning activities and adoption of mastery or learning goals to facilitate the learning of science content (Wentzel & Brophy, 2014), it may also lead to enhanced conceptual and meaningful learning. The position of the blocks of motivation and conceptual learning in Figure 6.1 indicates that conceptual learning (understanding) in science is seen (or projected as) a result of the enhanced motivation towards science learning (a student's tendency to understand science). It is important to note that embedded within the conceptual aspects of the intended learning are integral aspects of development of cognitive skills (HOCS and LOCS) and the addressing of misconceptions. Therefore, the *CLASS of Science* framework proposes to develop conceptual learning of secondary school students in science through enhancing their motivation towards science learning.

6.5. Methodological constraints and limitations

As commented by Cargill and O'Connor (2013), every study has some limitations associated with it, this study is no exception. It is one of the important aspects of any research to identify and acknowledge the issues that could potentially limit the nature and scope of a study. The present study is limited in terms of the following aspects, which might affect the generalisation of findings to different and other contexts:

1. The research was carried out in a particular Indian context. Given the diversity and the differences in school contexts among various Indian states, these

differences might potentially limit the transferability of findings to other contexts. Therefore, the findings may not be generalised to the entire student population throughout India. However, given the similarity of the schooling contexts in the north Indian states of Haryana, Punjab, Himachal Pradesh, Uttaranchal, Uttar Pradesh, Jammu and Kashmir, Delhi and Rajasthan, the findings may be generalised to the student populations from these states at the least.

2. The location of the research was a moderately large city in north of India which is under the direct administration of the central government (called a union territory). If it had been a metropolitan city such as New Delhi or Mumbai, or a village school context, then different results may have been achieved. The limiting factors from this aspect could have been infrastructure, support from the head, expertise of the teachers or/and a different classroom environment because of the differences in contexts.

3. The random assignment of students to the intervention and comparison groups which could not be carried out because of the on-going semester curriculum in the classrooms in the two participant schools. This may have changed the nature of the findings. Although, the four participating classrooms (groups) were shown to be comparable in terms of previous year's science achievement, students could not be assigned randomly to make it a true experimental research design. Obviously, a well planned and carried out experimental study would provide reliable results than quasi-experimental research.

4. Because of the adoption of the Solomon four-group research design for the study, the four groups (two intervention and two comparison) could not be equated for motivation levels before carrying out the teaching experiment. As a result of this, data from the two not-pretested groups (C and D; Figure 3.5) could not be included in the quantitative analysis of motivation data. The violation of the assumption of equivalence of the four groups therefore reduced the SMTSL findings to those obtained from the other two groups (A and B), which were pretested for equivalence.

5. Observation as a method of data collection could have been applied to explore and investigate the processes and phenomena from the observer's perspective.

This could provide important information about individual and group learning in detail and valuable insights to critique and evaluate the issues related with attitudes, motivation, views and experiences.

6. Although this thesis has tried to explore the factual, conceptual and procedural dimensions of learning along with its effectiveness on achievement and motivation, the meta-cognitive aspect of learning was not explored in detail. This aspect is a very important aspect of motivation and cognitive aspect of motivation to learn. The reasons behind the exclusion of the meta-cognitive aspects are the focus of the study, time constraints and the expertise of researcher.
7. Because the focus of the study was to enhance conceptual learning and motivation towards science learning of Indian secondary school students, misconceptions could not be addressed al length. This limitation can be ascribed to the time and space available, and management-related constraints of the study.
8. The prior knowledge of students could not be examined in detail because of the focus of the research and the time and space restrictions. Only science achievement was examined before implementing the intervention. However, there is a substantial amount of research that stresses the important role that prior knowledge plays in science learning and achievement.
9. Finally, the duration of the teaching experiment could have been for one complete year (school session) that spanned from 1st April to 31st of March including two months' study and examination breaks. This could provide information about the long term effect of the intervention, enhance the validity and reliability of the teaching experiment and strengthen the claims and conclusions of the study. This was not possible because of the distance between the sites of the research (schools in Chandigarh, India) and the institutional base of the researcher (Massey University in New Zealand).

6.6. Recommendations for further research

1. The application of design-based research methodology may open doors to the design, development, implementation and evaluation of similar interventions.

Prospective researchers can also iterate this intervention for longer durations or at different education levels or in other regions; national or international.

2. Because of time and space constraints, this research did not investigate the *meta-cognitive* dimension of knowledge of the revised Bloom's taxonomy (Krathwohl, 2002). However, there are some studies, such as by Leopold and Leutner (2015) and by Ritchhart, Turner, and Hadar (2009), which have explored these dimensions. Along the lines of these studies, the researcher recommends exploring the meta-cognitive dimensions of knowledge which are an important part of the *Revised Bloom's Taxonomy of Learning Teaching and Assessing* (Krathwohl, 2002) and may impact motivation and learning of science differently.

3. Researchers working in the area of motivation are encouraged to investigate the *motivation to learn* construct in different contexts and at different education levels. Detailed research regarding the collaborative, affective and cognitive dimensions of motivation and their impacts on students' performance is also needed.

4. The role of prior knowledge and its impact on the conceptual learning of science content is another important area in which to conduct research. Conceptual learning (especially HOCS and LOCS skills) can also be researched from the misconceptions point of view. Given the abstract nature of many science concepts at secondary school level, the identification and correction of misconceptions in secondary science is crucial.

5. Although this study applied a suitable but emerging methodology (DBR) and less common research design (Solomon four-group), researchers are recommended to conduct research applying different methodologies and designs which make sense to them and can produce reliable and valid findings.

6. Researchers are advised to think carefully about the methods of data generation before beginning the data collection so that essential, valid, robust and varied methods can be applied to explore different dimensions of constructs and voices of participants.

7. And finally, there is a need to replicate the study at different education levels and for a longer duration, which may add to the strength of the interpretations of findings and validity or refinement of the CCCM intervention.

6.7. Final thoughts

For most doctoral students, research is a journey or a voyage. But for me it was an odyssey. The online Oxford dictionary defines odyssey as, “A long and eventful or adventurous journey or experience” (Oxford Dictionaries Language Matters, 2016a). Very appropriate to the meaning, this odyssey has enriched me with many skills and competencies (which I think and feel) which resulted from numerous events, adventures, wanderings and most importantly never forgettable experiences. I have been through all the blood, sweat, and tears to fulfil the requirements of a doctorate degree in a foreign land. At this point of time I whole heartedly thank the Almighty God for providing me the courage and motivation to research *motivation* in classrooms. The odyssey took a start in the year 2006 when I started my teaching career as a teacher educator in a teacher training college in India. While supervising and supporting pre-service science teachers in the same year in schools, I realised and observed that students were neither learning science conceptually nor were they motivated to learn science. After many similar and repeated experiences, I decided to go for doctoral research with an intention to find some ‘quick-fix’/solutions to the problems faced by Indian students and science teachers. Given my background as a science, education and psychology post-graduate, and interest in ICT, I decided to research at the intersection of the four fields. Eventually, the area of research resulted to be educational technology and psychology in the field of science education.

Just before starting my PhD odyssey, I came across a report published by the Australian Council for Educational Research: *PISA 2009 Plus Results: Performance of 15-year-olds in reading, mathematics and science for 10 additional participants* (M. Walker, 2011), which to my surprise placed Indian secondary school students at 72nd place out of a total of 74 countries. At the same time, I was taking a course on advanced studies in motivation and learning which was based on recent theories and frameworks of learning and motivation. My earlier observations about the declining interests and low achievement levels of Indian secondary school students, along with the findings of the

ACER report created my interest in exploring conceptual learning and motivation of Indian students in detail. Therefore, I decided to study Indian secondary school students' motivation towards science learning along with their conceptual learning and achievement with an intention to improve the condition of school science education.

Considering the recent advancements in the critical field of learning and motivation and the explicit focus put worldwide on the development of learning and motivation in the form of functional 21st century skills (for details see Binkley et al., 2012), this thesis offers prospective means to apply the ATC21S™ framework (Griffin & Care, 2015) in practice through using the CCCM intervention. Findings of this study appear to be promising with respect to the 'call for action' recommendation of the Indian National Curriculum Framework 2005 and other UNESCO reports such as UNESCO (2013, 2014, 2015) to end the prevalent learning crisis in secondary science classrooms in the Indian and other international contexts.

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Appendices

Appendix A: Ground rules for collaborative learning

The success of classroom discussion (dialogue or talk) depends upon the degree to which participants understand and follow the *rules of the game* (Littleton & Mercer, 2013; Mercer & Littleton, 2007). These ground rules train participants about how to talk in accepted/required and particular ways. An understanding of how students and teachers use language to construct knowledge and understanding can help them to achieve the intended outcomes of planned collaborative activities. The ground rules for CCCM use were established based on the *Thinking together* and *Interthinking* approaches by Mercer and Littleton (2007) and, Littleton and Mercer (2013) studies respectively. As suggested by Mercer and Littleton (2007) the question: *what makes a classroom talk (discussion) productive and successful*, was brainstormed in the intervention classrooms in order to arrive at the collective ground rules for collaborative learning. The following ground rules were jointly established and agreed upon by the participating teachers, students and the researchers based on their experiences after the pilot teaching experiment, and were displayed in the intervention classrooms.

1. We take responsibility to contribute to the group work
2. We encourage our friends to add to group work and get engaged
3. We share and discuss our ideas and listen to each other
4. We respect each other's ideas and opinions
5. One person talks at a time and we listen patiently and give time to finish
6. We can politely disagree with the speaker and ask questions or for explanations
7. We give reasons and arguments to explain our ideas, opinions and disagreements
8. We support our friends in understanding the science concepts and frequently check whether or not everyone is understanding
9. We will keep the discussion and talk focussed around the concepts and will not discuss unnecessary life experiences
10. We will take turns to work on the computer to draw/design/edit the group concept map
11. We will show agreement and try to agree at the end of discussion to make the group work productive and to conclude the discussion

Appendix B: Letter from Massey University Human Ethics Committee

FILE

MASSEY UNIVERSITY
TE KUNENGA KI PŪREHUROA

12 October 2012

Anil Kaushik
89A Cook Street
PALMERSTON NORTH 4410

Dear Anil

Re: Computer-Based Collaborative Concept Mapping: Motivating Indian Secondary School Students to Learn Science

Thank you for your Low Risk Notification which was received on 28 September 2012.

Your project has been recorded on the Low Risk Database which is reported in the Annual Report of the Massey University Human Ethics Committees.

The low risk notification for this project is valid for a maximum of three years.

Please notify me if situations subsequently occur which cause you to reconsider your initial ethical analysis that it is safe to proceed without approval by one of the University's Human Ethics Committees.

Please note that travel undertaken by students must be approved by the supervisor and the relevant Pro Vice-Chancellor and be in accordance with the Policy and Procedures for Course-Related Student Travel Overseas. In addition, the supervisor must advise the University's Insurance Officer.

A reminder to include the following statement on all public documents:

> *"This project has been evaluated by peer review and judged to be low risk. Consequently, it has not been reviewed by one of the University's Human Ethics Committees. The researcher(s) named above are responsible for the ethical conduct of this research.*
>
> *If you have any concerns about the conduct of this research that you wish to raise with someone other than the researcher(s), please contact Professor John O'Neill, Director (Research Ethics), telephone 06 350 5249, e-mail humanethics@massey.ac.nz".*

Please note that if a sponsoring organisation, funding authority or a journal in which you wish to publish requires evidence of committee approval (with an approval number), you will have to provide a full application to one of the University's Human Ethics Committees. You should also note that such an approval can only be provided prior to the commencement of the research.

Yours sincerely

J.O'Neill

John G O'Neill (Professor)
Chair, Human Ethics Chairs' Committee and
Director (Research Ethics)

cc Dr Alison Kearney
School of Curriculum and Pedagogy
PN900

Dr Lone Jorgensen
School of Curriculum and Pedagogy
PN900

Mrs Roseanne MacGillivray
Graduate School of Education
PN900

Massey University Human Ethics Committee
Accredited by the Health Research Council

Research Ethics Office, Massey University, Private Bag 11222, Palmerston North 4442, New Zealand
T +64 6 350 5573 +64 6 350 5575 F +64 6 350 5622
E humanethics@massey.ac.nz animalethics@massey.ac.nz gtc@massey.ac.nz
www.massey.ac.nz

Appendix C: Letter to District Education Officer/DPI Schools

18 June, 2012
Sh. /Smt. [redacted], PCS
District Educationa officer/ DPI (Schools)
Department of Education
Chandigarh Administration

Re: Permission letter to carry-out research in Chandigarh schools

Dear Mr/Mrs [redacted],

My name is Anil Kaushik and I am a full-time doctoral (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. My research supervisors are Dr. Alison Kearney and Dr. Lone Jorgensen. My area of interest is secondary school science education and my research focus is on enhancement of learning and motivation in academic contexts through student collaboration and computer-based learning. Before starting my PhD studies, I was a teacher educator at Attri College of Education, Lalru in SAS Nagar district of Punjab. I completed both my B.Ed. and M.Ed. courses from Government College of Education, sector 20 Chandigarh.

I am writing this letter to seek your permission to carry out my intended research within the Chandigarh region. I would like to invite and work with two class IX science teachers and four grade 9 classrooms from two equivalent government schools of Chandigarh. The schools will be selected randomly but the classrooms will be adopted as existing to carry out the research. The purpose of my research is to investigate the effectiveness of *Computer-based Collaborative Concept Mapping* to make the process of science learning an *enjoyable experience* as suggested in the Indian National Curriculum Framework (NCF) 2005. The other details of the research are mentioned in the Information Sheet (attached with this letter).

A hard copy of this letter will be arriving soon in your office. Could you please send a scanned copy of the reply via my e-mail given below? If you require any further information about my planned research, please feel free to contact me, using the contact details listed below. I look forward to hearing from you.

Yours sincerely,
Anil Kumar Kaushik, Phone: +64 022 307 6939, E-mail: A.K.Kaushik@massey.ac.nz

Motivating Indian secondary school students to learn science

INFORMATION SHEET

(For Education Department Chandigarh Administration)

Dear Sir/Madam,

The proposed research is briefly described as following:

Purpose of the research

The purpose of this doctoral research is to explore students' motivation in academic contexts and to investigate the effectiveness of an intervention- *Computer-based Collaborative Concept Mapping* on their learning and motivation to learn. In particular, the study aims to explore the motivation to learn science, misconceptions in science, enablers and barriers in using the intervention and the influence of computer-based concept mapping and collaborative learning on these variables. Students' conceptual learning and their motivation to learn will be explored through the study of patterns of misconceptions and use of computer-based collaborative concept mapping. This study is an effort to design a better learning environment for secondary students, which in turn, may inform future pedagogical practices and models to enhance learning and motivation to learn.

Participants

The schools of Chandigarh are selected keeping in view the infrastructural facilities and implementation of innovative methods and techniques in their classrooms. Four (4) grade 9 classrooms will be selected randomly from two equivalent (in terms of achievement) government schools of Chandigarh. One classroom from each school will be taught using the *Computer-based Collaborative Concept Mapping* intervention and the other schools will be taught using their normal teaching-learning methods. At the end of two months, the four schools will be post-tested to study any gain in their learning and motivation to learn. To study the long term effects, I am planning to carry out the intervention for the next six months, if and only if the administration, the school principals, the science teachers and students feel comfortable and satisfied in the use of intervention. Achievement tests and a questionnaire will be delivered to students. At the end of the study 16 students (four from each classroom) and two science teachers will be interviewed.

Permission and invitation procedure

If you allow for my research, then the two school principals will be contacted to seek their permission to carry out the intervention. The consent forms will be given to two science teachers, students and their parents to invite them to participate in the study. The study will only be carried out after getting the necessary consents and no data will be collected before this procedure is completed.

Participants' rights

The participants are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If they decide to participate, they will have the right to:

- Withdraw themselves and the information they have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during the interview
- Ask any questions about the study at any time during their participation
- Provide information on the understanding that their name will not be used unless they give permission to the researcher; and
- To be given access to a summary of the results when these are concluded.

Person to contact in case of any concerns and questions

Doctoral student
Anil Kumar Kaushik
School of Curriculum and Pedagogy
College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 022 307 6939
Email: A.K.Kaushik@massey.ac.nz

Doctoral Supervisor
Dr. Alison Kearney
Head of the School of Curriculum & Pedagogy,
College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 06 356 9099 ext 8704
Email: A.C.Kearney@massey.ac.nz

Approval letter from the District Education Officer

O/o THE DISTRICT EDUCATION OFFICER : CHANDIGARH ADMINISTRATION

Endst. No.: DEO/UT/E-5/2012/13866-69 Dated: 17/07/12

OFFICE ORDER

Permission is hereby accorded to Sh. Anil Kumar Kaushik, School of Curriculum and Pedagogy, College of Education, Massey University, Private Bag, Palmerston North New Zealand for research in Govt. Model Sr. Sec. School, Sector 19-C, UT Chandigarh and Govt. Model Sr. Sec. School, Sector 21, UT Cha[redacted] to the condition that there is no loss of st[redacted] students and Principal, Teachers and Students feel comfortable and satisfied with the intervention.

Sd/-

District Education Officer,
Chandigarh Administration.

Endst. No.: Even Dated:

A copy is forwarded to the following for information and necessary action: -

1. The Director Public Instruction (S), Chandigarh Administration.
2. Govt. Model Sr. Sec. School, Sector 19-C, UT Chandigarh.
3. Govt. Model Sr. Sec. School, Sector 21, UT Chandigarh.
4. Sh. Anil Kumar Kaushik, School of Curriculum and Pedagogy, College of Education, Massey Universi[redacted] Bag 11 222, Palmerston North New Zealand. [redacted]

District Education Officer,
Chandigarh Administration.

Appendix D: Letters to School Principals

Motivating Indian secondary school students to learn science

INFORMATION SHEET
(For School/ Principal)

The Principal/ Head, ____

Dear ______________________________________

My name is Anil Kaushik and I am a full-time doctoral (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. My research supervisors are Dr. Alison Kearney and Dr. Lone Jorgensen. My area of interest is secondary school science education and my research focus is on the enhancement of learning and motivation in academic contexts through student collaboration and computer-based learning. Before starting my PhD studies, I was a lecturer in Attri College of Education, Lalru in SAS Nagar district of Punjab. I completed both my B.Ed. and M.Ed. courses from Government College of Education, Sector 20 Chandigarh. I am writing this letter to seek your permission to carry out my research in your school, to contact the subject teacher and students and invite them to participate in my research.

Project Description and Invitation

The purpose of this doctoral research is to explore secondary students' motivation in academic contexts and to investigate the effectiveness of an intervention: *Computer-based Collaborative Concept Mapping* on their learning and motivation to learn science. In particular the study aims to explore the motivation to learn science, misconceptions in science, enablers and barriers in using the intervention and the influence of computer-based concept mapping and collaborative learning on these variables. This project is an effort to make the process of science learning an *enjoyable experience* as suggested in the Indian National Curriculum Framework (NCF) 2005. In particular, this study is an effort to design a better learning environment for secondary students, which in turn, may inform future pedagogical practices and models to enhance learning and motivation to learn. I would like to invite and work with one grade (class) 9 science teacher and two grade 9 classrooms from your school.

Research procedure

Four (4) grade 9 classrooms are selected randomly from two equivalent (in terms of achievement) government schools of Chandigarh. Your school is selected randomly but the classrooms will be adopted as existing to carry out the research to avoid any disturbances in the on-going classroom work. One classroom from each school will be taught using the *Computer-based Collaborative Concept Mapping* intervention and the other classroom from each school will be taught using their normal teaching-learning methods. At the end of two months, the four classrooms will be post-tested to study any gain in their learning and motivation to learn. To study the long term effects, I am planning to carry out the intervention for the next six months, if and only if the administration, the school principals, the science teachers and students feel comfortable and satisfied with the use of intervention. Achievement tests and a questionnaire will be delivered to students. Two groups of five students from a class will be invited to participate in the group discussion to assess their conceptual learning. At the end, the science teacher will be interviewed.

Data management

Data such as the interview transcripts, field notes and other records will be stored securely throughout the research process. These will be kept in a securely locked filing cabinet at my workplace while in India and in the postgraduate study room in the Massey University in New Zealand. The data will be kept on the researcher's computer hard drive protected and retrieved by a password. The backup of data will also be saved in a flash drive on which only code names will appear on data. Data and consent forms will be stored separately. Findings will be presented in my thesis as well as other academic publications and presentations.

Participants' rights

The participation of the science teacher and students is voluntary. The participants are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If they decide to participate, they will have the right to:

- Withdraw themselves and the information they have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during the interview
- Ask any questions about the study at any time during their participation
- Provide information on the understanding that their name will not be used unless they give permission to the researcher; and
- To be given access to a summary of the results when these are concluded.

Permission and invitation procedure

If you agree to allow the research, I will send an invitation letter with information sheet and a consent form to the science teacher, describing my research and inviting him/her to participate. The consent forms will be given to students to invite them to participate and to their parents to seek permission to allow them to participate in the study. The study will only be carried out after getting the necessary consents and no data will be collected before this procedure is completed.

If you agree to allow this research to be carried out in your school, could you please sign the attached consent form and return it to me.

If you require any further information about my planned research, please feel free to contact me, using the contact details listed below.

I look forward to hearing from you.

Yours sincerely,
Anil Kumar Kaushik
Phone: +91 94671 05995, +64 022 307 6939
E-mail: A.K.Kaushik@massey.ac.nz

Persons to contact in any concerns/questions

If you have any questions, please feel free to contact me or you can contact my supervisor Dr. Alison Kearney via her contact details given below:

Doctoral student

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Doctoral Supervisor

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Extension 8704
Email: A.C.Kearney@massey.ac.nz

CONSENT FORM
(For School/ Principal)

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw the school from the study at any time.

I agree to allow the teachers at this school to collaborate with the researcher on the understanding that the name of the school, and of the teachers and students who participate, will not be used.

I agree to allow the subject teacher and students to participate in this study under the conditions set out in the Information Sheet.

Signature: _______________________ Date: ___________________

Full name: ____

School: ____

School stamp: ____

Appendix E: Letters to participant teachers

Motivating Indian secondary school students to learn science

INFORMATION SHEET
(For Teacher participant)

Dear ___________________________________

I would like to introduce myself and tell you a little about my research before inviting you to participate. My name is Anil Kaushik and I am a full-time doctoral (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. My research supervisors are Dr. Alison Kearney and Dr. Lone Jorgensen. My area of interest is secondary school science education and my research focus is on the enhancement of learning and motivation in academic contexts through student collaboration and computer-based learning. Before starting my PhD studies, I was a teacher educator at Attri College of Education, Lalru in SAS Nagar district of Punjab. I completed both my B.Ed. and M.Ed. courses from Government College of Education, Sector 20 Chandigarh. I am writing this letter to invite you and to seek your consent to participate in my research.

Project Description and Invitation

The purpose of this doctoral research is to explore students' motivation in academic contexts and to investigate the effectiveness of an intervention- *Computer-based Collaborative Concept Mapping* on their learning and motivation to learn science. In particular, the study aims to explore the motivation to learn science, misconceptions in science, enablers and barriers in using the intervention and the influence of computer-based concept mapping and collaborative learning on these variables. This project is an effort to make the process of science learning an *enjoyable experience* as suggested in the Indian National Curriculum Framework (NCF) 2005. In particular, this study is an effort to design a better learning environment for secondary students, which in turn, may inform future pedagogical practices and models to enhance learning and motivation to learn.

Research procedure

Four (4) grade 9 classrooms are selected randomly from two equivalent (in terms of achievement) government schools of Chandigarh. This school is selected randomly but the classrooms will be adopted as existing to carry out the research to avoid any disturbances in the on-going classroom work. One classroom from each school will be taught using the *Computer-based Collaborative Concept Mapping* intervention and the other classroom from each school will be taught using their normal teaching-learning methods. At the end of two months, the four classes will be post-tested to study any gain in their learning and motivation to learn. To study the long term effects, I am planning to carry out the intervention for the next six months, if and only if the administration, the school principals, the science teachers and students feel comfortable and satisfied with the use of the intervention

What is involved?

If you agree to participate in the research you are invited to participate in/carry out the following activities:

- First of all, I would like to invite you to attend an orientation/workshop for a week at the State Institute of Education (SIE), Chandigarh administration, to use the concept mapping software effectively in classrooms. The timings will be decided for your convenience keeping in mind your schedule in the school.
- Then, I plan to pre-test one of the grade-9 classes of students by an achievement test to check their prior knowledge in the contents to be covered. The students will also be given a questionnaire to measure their motivation to learn science.
- You are requested to teach two grade 9 classrooms for two months. The workload will be discussed with your school principal. The one classroom will be taught using your traditional/natural method of teaching. The other class will be taught by using an educational concept mapping software- *Inspiration9* and students working and learning in groups. The researcher will assist you in any case of query or concern related to teaching and instruction.
- At the end of two months, I plan to post-test the achievement of students of two classes using an achievement test and the motivation questionnaire again. Two groups of five students from a class will be invited to participate in a group discussion.
- An interview (of one hour maximum) involving questions about your experiences of using the software in the classroom, of collaborative learning and computer-based learning, and any difficulties faced while using collaborative learning using concept mapping will be conducted at the end of the study.
- Finally, prior to making any contact with potential student participants and their parents, I would request that you introduce the project to students using the information given at the beginning of this information sheet.

My duties as a researcher

All information collected will be confidential and the data such as the interview transcripts, field notes and other records will be stored securely throughout the research process. These will be kept in a securely locked filing cabinet at my workplace while in India and in a secure place in the postgraduate study room in the Massey University in New Zealand. The data will be kept on the researcher's computer hard drive protected and retrieved by a password. The backup of data will also be saved in a flash drive on which only code names appear on data. Data and the consent forms will be stored separately.

If you choose I will send you a summary of the research results once they are available. Once complete, the findings will be presented in my thesis as well as other academic publications and presentations. My thesis will be available through the Massey University library both in printed and electronic versions.

Your rights as participants

Your participation in the research is voluntary. You are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If you decide to participate, you will have the right to:

- Withdraw yourself and the information you have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during the interview
- Ask any questions about the study at any time during participation
- Provide information on the understanding that your name will not be used unless you give permission to the researcher; and
- To be given access to a summary of the results when these are concluded.

If you agree to participate in this research, could you please sign the attached consent form and return it to me.

Thank you very much for your time and responding.

Sincerely,
Anil Kumar Kaushik

Persons to contact in any concerns/questions

If you have any questions, please feel free to contact me or you can contact my supervisor Dr. Alison Kearney via her contact details given below:

Doctoral student: Anil Kumar Kaushik

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College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
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+91 94671 05995
Email: A.K.Kaushik@massey.ac.nz

Doctoral Supervisor: Dr. Alison Kearney

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Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 06 356 9099
Extension 8704
Email: A.C.Kearney@massey.ac.nz

CONSENT FORM
(For teacher participant)

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw myself from the study at any time.

(Please tick the appropriate box)

I agree ☐ / do not agree ☐ to be interviewed.

I agree ☐ / do not agree ☐ to the interview being audio taped.

I want ☐ / do not want ☐ my audio file of the interview returned to me.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: ________________________ Date: ____________________

Full name: ____

Position in the School: ____

Appendix F: Letters to parents of student participants

Motivating Indian secondary school students to learn science

INFORMATION SHEET
(For parents of student participants)

Dear Parent,

I would like to introduce myself and tell you a little about my planned research before seeking your permission to allow your child to participate in my research. My name is Anil Kaushik and I am a full-time doctoral (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. My research supervisors are Dr. Alison Kearney and Dr. Lone Jorgensen. My area of interest is secondary school science education and my research focus is on the enhancement of learning and motivation in academic contexts through student collaboration and computer-based learning. Before starting my PhD studies, I was a teacher educator at Attri College of Education, Lalru in SAS Nagar district of Punjab. I completed both my B.Ed. and M.Ed. courses from Government College of Education, Sector 20 Chandigarh. I am writing this letter to seek your consent to allow your child to participate in my research.

Purpose of research and invitation

The purpose of this doctoral research is to explore students' motivation in academic contexts and to investigate the effectiveness of a computer-based method of teaching and learning on their learning and motivation to learn science. In particular, the study aims to explore students' motivation to learn science, misconceptions in science, as well as the enablers and barriers in using the method and the influence of this method on these variables.

You might be aware of the poor performance of Indian secondary school students in science from recently out results of PISA+ (2009) at international level. According to the surveys conducted by NCERT and ASER, results at the national level are also not satisfactory. There could be various reasons for this poor performance and some of them could be conceptual learning, motivation to learn, style of assessment, methods of teaching and learning and so forth. This research project is an effort to make the process of science learning an *enjoyable experience* as suggested in the Indian National Curriculum Framework (NCF) 2005. In particular, this study is an effort to design a better learning environment for secondary students, which in turn, may inform future pedagogical practices and models to enhance learning, motivation to learn and classroom achievement.

What is involved?

If you allow your child to participate in this research, I would like to invite them to participate in the following activities:

- First of all, I plan to pre-test the student participants by an achievement test to check their current knowledge in the contents to be covered. The students will also be given a questionnaire to measure their motivation to learn science.
- Then for the next two months, the students will study/learn their science contents using educational software called *Inspiration-9*. A sufficient amount of research supports the effectiveness of this method to enhance the learning achievement in science. The students will be learning in small groups of 4-5 students in the class and working on the computers. Their class teachers will ensure their effective learning in the class.
- After two months of the study, I plan to conduct the achievement test and questionnaire to check any gain in their learning, achievement and motivation to learn.
- Finally, I plan to conduct group discussion of two groups of five students each to assess their conceptual learning in science.

My duties as a researcher

All information collected will be confidential and the data such as the interview transcripts, field notes and other records will be stored securely throughout the research process. These will be kept in a securely locked filing cabinet at my workplace while in India and in a secure place in the postgraduate study room in the Massey University in New Zealand. The data will be kept on the researcher's computer hard drive protected and retrieved by a password. The backup of data will also be saved in a flash drive on which only code names will appear on data. Data and consent forms will be stored separately.

Participants' rights

The participation of students is voluntary. The participants are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If they decide to participate, they will have the right to:

- Withdraw themselves and the information they have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during the interview
- Ask any questions about the study at any time during their participation; and
- Provide information on the understanding that their name will not be used unless they give permission to the researcher.

If you agree to allow your child to participate in the research project, I will contact your child/ward to invite him/her to participate in the research. The study will only be carried out after getting the necessary consents and no data will be collected before this procedure is completed.

If you agree to include your child in the research, could you please sign the consent form attached with this letter.

Thank you very much for your time and responding.

Sincerely,
Anil Kumar Kaushik
Phone: +91 94671 05995, +64 022 307 6939, E-mail: A.K.Kaushik@massey.ac.nz

If you have any questions, please feel free to contact me or you can contact my supervisor Dr. Alison Kearney via her contact details given below:

Doctoral student

Anil Kumar Kaushik
School of Curriculum and Pedagogy
College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 02230 76939
+91 94671 05995
Email: A.K.Kaushik@massey.ac.nz
Doctoral Supervisor

Dr. Alison Kearney
Head of the School of Curriculum & Pedagogy, College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 06 356 9099
Extension 8704
Email: A.C.Kearney@massey.ac.nz

CONSENT FORM

(For parents of student participants)

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw my child from the study at any time.

(Please tick the appropriate box)

I agree ☐ / do not agree ☐ for my child to participate in group interview.

I agree ☐ / do not agree ☐ to the group interview being audiotaped

I agree ☐ / do not agree ☐ to the group interview being videotaped.

I agree for my child to participate in this study under the conditions set out in the Information Sheet.

Signature: ______________________ Date: __________________

Full name: ____

Relation to the student: _________________________________

School: ____

Class: _____________ Student Roll number: _________

Student Initials: __________ (for example: for **A**nil **K**umar **K**aushik, write AKK)

Appendix G: Letters to student participants- Intervention groups

Motivating Indian secondary school students to learn science

INFORMATION SHEET

(For student participants- IG)

Dear student,

My name is Anil Kaushik and I am a full-time research (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. I am here in your school to conduct my research. The aim of my research is to find an effective method of teaching and learning, so that, your school and class teacher can use and carry out this method to ensure your better learning. I am writing this letter to invite you to participate in this research. The details of the activities are as following:

- First of all, you will be given a list of questions and a test to check your current knowledge in science. This will help us to decide and carry out better method of teaching and learning.
- After that you will learn in small groups by group discussion and using educational software on computer and working in groups for two months.
- A list of questions and a test of science will be given to you again after two months. This will help us to check if your knowledge has increased or not and if you like and enjoy the method of learning.
- After that, two groups of students will be selected to participate in a group discussion about the study and to share their experiences with me.
- You are requested to cooperate and participate honestly in the research so that we can apply the best method of teaching and learning in your class after this research has completed.

Your rights as participants

Your participation in the research is voluntary. You are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If you decide to participate, you will have the right to:

- Withdraw yourself and the information you have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during group discussion
- Ask any questions about the study at any time during participation; and
- Provide information on the understanding that your name will not be used unless you give permission to the researcher.

My duties as a researcher

It is my duty to help you to feel you comfortable with the research and activities to be carried out. All the data collected will be placed in secure place so that no one can reach and use it. Your names will be kept confidential and will not be mentioned in the research. I would like to tell that you will like the method and enjoy it to learn science syllabus in a better way.

If you agree to participate in this research, could you please sign the attached consent form and return it to me.

Thank you very much for your time and responding.

Kind regards,
Anil Kumar Kaushik
Phone: +91 94671 05995, +64 022 307 6939, E-mail: A.K.Kaushik@massey.ac.nz

Persons to contact in any concerns/questions

If you have any questions, please feel free to contact me or you can contact my supervisor Dr. Alison Kearney via her contact details given below:

Doctoral student

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Doctoral Supervisor

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Palmerston North New Zealand
Phone: +64 06 356 9099
Extension 8704
Email: A.C.Kearney@massey.ac.nz

CONSENT FORM

(For student participants- IG)

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw myself from the study at any time.

(Please tick the appropriate box)

I agree ☐ / do not agree ☐ to participate in a group discussion.

I agree ☐ / do not agree ☐ to the discussion being audiotaped.

I agree ☐ / do not agree ☐ to the discussion being videotaped.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: ______________________ Date: __________________

Name of student: ____

Name of the School: ____

Class: ______________________ Roll no: __________________

Letters to student participants- Comparison groups

Motivating Indian secondary school students to learn science

INFORMATION SHEET
(For student participants- CG)

Dear student,

My name is Anil Kaushik and I am a full-time research (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. I am here in your school to conduct my research. The aim of my research is to find an effective method of teaching and learning, so that, your school and class teacher can use and carry out this method to ensure your better learning. I am writing this letter to invite you to participate in this research. The details of the activities are as following:

- First of all, you will be given a list of questions and a test to check your current knowledge in science. This will help us to decide and carry out better method of teaching and learning.
- After that you will learn your science syllabus according to your normal method of learning and teaching.
- A list of questions and a test of science will be given to you to fill in again after two months. This will help us to check if your knowledge has increased or not.
- After that, two groups of students will be selected to participate in a group discussion about the study and to share their experiences with me.
- You are requested to cooperate and participate honestly in the research so that we can apply the best method of teaching and learning in your class after this research has completed.

Your rights as participants

Your participation in the research is voluntary. You are under no obligation to accept the invitation. The schools and participants will not be named in the publication of research findings because of the issues of anonymity and confidentiality. If you decide to participate, you will have the right to:

- Withdraw yourself and the information you have contributed at any time and stage of the research
- Decline to answer any particular question during the interview
- Ask for the recording to be stopped at any time during group discussion
- Ask any questions about the study at any time during participation; and
- Provide information on the understanding that your name will not be used unless you give permission to the researcher.

My duties as a researcher

It is my duty to help you to feel you comfortable with the research and activities to be carried out. All the data collected will be placed in secure place so that no one can reach and use it. Your names will be kept confidential and will not be mentioned in the research.

If you agree to participate in this research, could you please sign the attached consent form and return it to me.

Thank you very much for your time and responding.

Kind regards,
Anil Kumar Kaushik
Phone: +91 94671 05995, +64 022 307 6939, E-mail: A.K.Kaushik@massey.ac.nz

Persons to contact in any concerns/questions

If you have any questions, please feel free to contact me or you can contact my supervisor Dr. Alison Kearney via her contact details given below:

Doctoral student

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Palmerston North New Zealand
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Doctoral Supervisor

Dr. Alison Kearney
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Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 06 356 9099
Extension 8704
Email: A.C.Kearney@massey.ac.nz

CONSENT FORM

(For student participants- CG)

I have read the Information Sheet and have had the details of the study explained to me. My questions have been answered to my satisfaction, and I understand that I may ask further questions at any time.

I understand that I have the right to withdraw myself from the study at any time.

(Please tick the appropriate box)

I agree ☐ / do not agree ☐ to participate in a group discussion.

I agree ☐ / do not agree ☐ to the discussion being audiotaped.

I agree ☐ / do not agree ☐ to the discussion being videotaped.

I agree to participate in this study under the conditions set out in the Information Sheet.

Signature: ________________________ Date: ____________________

Name of student: ____

Name of the School: ____

Class: ________________________ Roll no: ____________________

Appendix H: Achievement Test in Science for Grade 9

ATS9

School: .... Class & Section.................

Roll No. .... Name: .... Male/Female.....................

Note: Please write your answer in the space provided in these sheets only.

Questions 1-10 are Multiple Choice Questions and carry 1 mark each.
Questions 11-20 are very short answer type questions and carry 1 mark each, and
Questions 21-35 are short answer type questions and carry 2 marks each.

Time allowed: 1 Hour **Maximum marks: 50**

Q 1. Correlate the following:

Phosphorus molecule: P_4

Sulphur molecule: _____

Choice: a) S_2 b) S_3 c) S_6 d) S_8

Q 2. The molecular formula for Aluminium sulphate is:

a) $Al_2(SO_4)_3$ b) $AlSO_4$ c) $Al_3(SO_4)_2$ d) $Al_2(SO_4)_4$

Q 3. Number of valence electrons in the Cl^- ion is:

a) 1 b) 7 c) 8 d) 3

Q 4. According to Bohr-Bury scheme, the maximum number of electrons which can be accommodated in a given shell is given by the formula:

a) 2n b) n^2 c) $2n^2$ d) $3n^2$

Q 5. The animals having two chambered heart belong to the class:

a) Ambhibia b) Reptilia c) Pisces d) Aves

Q 6. The organisms having 'pores' all over the body and a canal system for bringing in food and oxygen belongs to phylum:

a) Coelenterata b) Annelida c) Echinodermata d) Porifera

Q 7. Which would have the greater effect on kinetic energy of the object?

a) Mass b) acceleration c) inertia d) velocity

Q 8. The cgs unit of work is

a) Joule b) erg c) dyne d) watt

Q 9. Which of the sound waves can we hear?

a) 16Hz b) 25000 Hz c) 31000 Hz d) 50 Hz

Q 10. When is the velocity of sound highest?

a) During winters b) during summer c) during rainy season d) No difference

Q 11. What is the difference between an atom and a molecule?

Q 12. Calculate molecular mass of C_2H_6

Q 13. Write distribution of electrons (electronic configuration) of Na^+ ion and Na atom.

Q 14. What are the valences of Mg and O atoms?

Q 15. Correlate the following

a) Plants with naked seeds : Gymnosperms
b) Plants with seeds enclosed in fruits: ....

Choice: Angiosperrms, Bryophyta , Pteridophyta, Thallophyta

Q 16. Name the class:

The animals belonging to this class are cold-blooded, have scales and breathe through lungs.

Q 17. When do we say that one Joule work is done?

Q 18. A man is pulling water from a well. State whether work done by the man is positive or negative? Explain why?

Q 19. How does the sound produced by your school bell reach your ears?

Q 20. Flash and thunder are produced simultaneously. But thunder is heard a few seconds after the flash is seen, why?

Q 21. What are diatomic and triatomic molecules? Give examples.

Q 22. If one mole of C atoms has a mass of 12 g, what is the mass of one atom of C in grams?

Q 23. The number of electrons in the outermost shell M of an atom is 5.

a) Write its electronic configuration b) what is its valency and why?

Q 24. Give two differences and two similarities between ${}_{17}Cl^{35}$ and ${}_{17}Cl^{37}$.

Q 25. In Rutherford α-scattering experiment, some of α particles were deflected through small and some were deflected through large angles. What does this indicate/prove?

Q 26. Differentiate between fungi and plants.

Q 27. Write two characteristics of amphibians.

Q 28. Characteristics of some organisms are given. Identify their group and give one example:

a) Single celled, eukaryotic, and photosynthetic
b) Multi-cellular, eukaryotic, and do not perform photosynthesis

Q 29. The velocity and kinetic energy of an object are 10m/s and 200 Joule respectively.

a) Calculate its K.E. if velocity is halved?
b) Calculate its K.E. if velocity is increased 3 times.

Q 30. What happens to the kinetic energy when-?

a) The mass of the body is doubled
b) The velocity of the body is doubled

Q 31. When an arrow is shot from a bow, it gets kinetic energy. Where does it get this kinetic energy from?

Q 32. A light and a heavy body have same kinetic energy. Which one will have greater momentum? And why?

Q 33. An echo is heard in 7seconds. What is the distance of the reflecting surface from the source if the speed of sound in air is 342 m/s.?

Q 34. A stone is dropped from the top of the tower 400 m high in to a well 100 m deep. When is the splash heard at the top? (Given g = 10 m/s^2 and speed of sound is 340 m/s)

Q 35. How is ultrasound used for cleaning? Give its two other applications.

Appendix I: Assessment Rubric for Achievement test ATS9

Knowledge and Cognitive process dimension	*Response category*			
	Advanced	***Proficient***	***Intermediate***	***Novice***
Conceptual knowledge-Cognitive processes	Answer shows explicit and thorough understanding of basic concepts in terms of suitable keywords. Appropriate use of theories, models and principles with accurate scientific terminology. Use of reasoning, articulation and argument to explain a concept. Shows deep understanding of the issues and concepts.	Answer demonstrates clear understanding of the concept in terms of accurate scientific terminology, reasoning, and explanation. Shows clear definition and examples. Can apply this understanding to solve problems but lacks analysis and evaluation of information (no/few evidence of higher order thinking skills).	Answer shows limited or some understanding of basic concepts and their relationships. Lacks reasoning, explanation and examples to support the evidence/answer. Shallow and partial learning evidence.	Produces insufficient evidence to demonstrate concept learning. Shows poor or faulty understanding of concepts and relationship between concepts. Answer demonstrates significant misconceptions. Incorrect answer or failed to answer.
Procedural knowledge-Cognitive processes	Answer shows explicit procedural knowledge to solve problems. Shows evidence of analysis and evaluation processes along with accurate procedures to solve a scientific problem with correct answer and articulation.	Answer shows correct procedure to solve a problem and a correct answer but lacks articulation and analysis of the problem. Limited or no evidence of accurate/alternative procedures to reach to a solution.	Answer demonstrates correct procedure but the solution is not complete. OR: Shows some understanding of the procedure. OR: The answer may be correct but lacks correct procedure.	No/insufficient evidence of correct procedural knowledge to solve a problem. No evidence of the correct steps of the correct procedure.

Appendix J: Student's Motivation towards Science Learning questionnaire

The SMTSL Questionnaire

School: .... Class & Section..................

Roll No........... Name.. Male/Female......................

Directions for students

This questionnaire contains statements about your willingness in participating in this science class. You will be asked to express your agreement on each statement. There are no "right" or "wrong" answers. Your opinion is what is wanted. Think about how well each statement describes your willingness in participating in this class.

Draw a circle around

1 - *if you strongly disagree (SD) with the statement;*
2 - *if you disagree (D) with the statement;*
3 - *if you have no opinion (NO) about the statement;*
4 - *if you agree (A) with the statement; and*
5 - *if you strongly agree (SA) with the statement.*

- Be sure to give an answer for all questions. If you change your mind about an answer, just cross it out and circle another.
- Some statements in this questionnaire are fairly similar to other statements. Don't worry about this. Simply give your opinion about all statements.

	A. Self-efficacy	**Strongly Disagree**	**Disagree**	**No opinion**	**Agree**	**Strongly agree**
1	Whether the science concept/content is difficult or easy, I am sure that I can understand it.	1	2	3	4	5
2	I am not confident about understanding difficult science concepts. (-)	1	2	3	4	5
3	I am sure that I can do well on science tests.	1	2	3	4	5
4	No matter how much effort I put in, I cannot learn science. (-)	1	2	3	4	5
5	When science topics are too difficult, I give up or only do the easy parts. (-)	1	2	3	4	5
6	During science activities, I prefer to ask other people for the answer rather than think for myself. (-)	1	2	3	4	5
7	When I find the science topics/content difficult, I do not try to learn them. (-)	1	2	3	4	5

	B. Active Learning Strategies	SD	D	NO	A	SA
8	When learning new science concepts, I attempt to understand them.	1	2	3	4	5
9	When learning new science concepts, I connect them to my previous knowledge/experiences.	1	2	3	4	5
10	When I do not understand a science concept, I find relevant information/resources that will help me.	1	2	3	4	5
11	When I do not understand a science concept, I would discuss with the teacher or other students to clarify my understanding.	1	2	3	4	5
12	During the learning process, I attempt to make connections between the concepts that I learn.	1	2	3	4	5
13	When I make a mistake, I try to find out why.	1	2	3	4	5
14	When I meet science concepts that I do not understand, I still try to learn them.	1	2	3	4	5
15	When new science concepts that I have learned conflict with my previous understanding, I try to understand why.	1	2	3	4	5

	C. Science Learning Value	SD	D	NO	A	SA
16	I think that learning science is important because I can use it in my daily life.	1	2	3	4	5
17	I think that learning science is important because it develops/stimulates my thinking.	1	2	3	4	5
18	In science, I think that it is important to learn to solve problems.	1	2	3	4	5
19	In science, I think it is important to participate in inquiry activities.	1	2	3	4	5
20	It is important to have the opportunity to satisfy my own curiosity when learning science.	1	2	3	4	5

	D. Performance Goals	SD	D	NO	A	SA
21	I participate in science classes/courses to get a good grade. (-)	1	2	3	4	5
22	I participate in science classes/courses to perform better than other students. (-)	1	2	3	4	5
23	I participate in science classes/courses so that other students think that I'm smart. (-)	1	2	3	4	5
24	I participate in science classes/courses so that the teacher pays attention to me. (-)	1	2	3	4	5

	E. Achievement Goals	SD	D	NO	A	SA
25	During a science class, I feel most satisfied when I attain a good score in a test.	1	2	3	4	5
26	I feel most satisfied when I feel confident about the content in a science class.	1	2	3	4	5
27	During a science class, I feel most satisfied when I am able to solve a difficult problem.	1	2	3	4	5
28	During a science class, I feel most satisfied when the teacher accepts my ideas.	1	2	3	4	5
29	During a science class, I feel most satisfied when other students accept my ideas.	1	2	3	4	5

	F. Learning Environment Stimulation	SD	D	NO	A	SA
30	I am willing to participate in this science class because the content is exciting and challenging.	1	2	3	4	5
31	I am willing to participate in this science class because the teacher uses a variety of teaching methods.	1	2	3	4	5
32	I am willing to participate in this science class because the teacher does not put a lot of pressure on me.	1	2	3	4	5
33	I am willing to participate in this science class because the teacher pays attention to me.	1	2	3	4	5
34	I am willing to participate in this science class because it challenges my understanding.	1	2	3	4	5
35	I am willing to participate in this science class because the students are involved in discussions.	1	2	3	4	5

Appendix K: Permission to use the SMTSL questionnaire

RE: Permission to use the SMTSL questionnaire
From: Tuan<suhltuan@cc.ncue.edu.tw>
Sent: Thu 14/06/2012 12:46 p.m.
To: Kaushik, Anil <A.K.Kaushik@massey.ac.nz>

Dear Anil Kaushik,
Thanks for your interests in my questionnaire. You are welcome to use this questionnaire in your research.
Hsiao-Lin Tuan
Graduate Institute of Science Education
National Changhua University of Education
Changhua, Taiwan

From: Kaushik, Anil [mailto:A.K.Kaushik@massey.ac.nz]
Sent: Thursday, June 14, 2012 7:21 AM
To: suhltuan@cc.ncue.edu.tw
Subject: Permission to use the SMTSL questionnaire

14 June, 2012
Hsiao-Lin Tuan
National Changhua University of Education Taiwan

Re: Permission to use the SMTSL questionnaire in doctoral research
Dear Mr. Tuan,
My name is Anil Kaushik and I am a full-time doctoral (PhD) student in the School of Curriculum and Pedagogy, College of Education, Massey University, New Zealand. My research supervisors are Dr. Alison Kearney and Dr. Lone Jorgensen. My area of interest is secondary school science education and my research focus is on enhancement of learning and motivation in academic contexts through student collaboration and computer-based learning. Before starting my PhD studies, I was a teacher educator in an Education college in India.
I am writing this letter to seek your permission to use the questionnaire to measure Students' Motivation towards Science Learning (SMTSL) developed by your team. While reviewing the literature on student motivation, I fortunately found the questionnaire. I found it very relevant to my study.
Dear sir/madam, could you please allow me to use the questionnaire in my study. I look forward to hearing from you.

Yours sincerely,
Anil Kumar Kaushik
PhD candidate, School of Curriculum and Pedagogy
College of Education
Massey University, Private Bag 11 222
Palmerston North New Zealand
Phone: +64 022 307 6939, Email: A.K.Kaushik@massey.ac.nz

Appendix L: Concept Map Analysis Rubric

Category of the quality of concept map		
Proficient	***Intermediate***	***Novice***
The concept map demonstrates clear and explicit understanding of the concepts in terms of accurate scientific terminology, reasoning, and explanation. Shows clear definition and examples. There is evidence of valid linkage between concepts to compare-contrast, analysis and evaluation of information. The choice of linking words is appropriate	The concept map shows limited or shallow understanding of basic concepts and their relationships. The map lacks explicit demonstration of reasoning, explanation and examples. Some of the links are not valid and there is some confusion at some places in the map. There are few indications of valid examples and cross linkage and incorrect presentation of information is present.	The concept map produces insufficient evidence to demonstrate concept learning. It shows poor or faulty understanding of relationships between concepts. The concept map demonstrates presence of misconceptions and incorrect presentation of the content. There are very few valid concepts and a lot of confusion is demonstrated in the concept map.

Appendix M: Teacher Interview guiding questions

Participants: Two science teachers- one from each school

Objectives: To explore teachers' perceptions and experiences of using CCCM in their classrooms, and to record enablers for and barriers to the CCCM use in science classrooms.

Interview questions

1. What do you think about the uses of concept mapping and concept mapping software in teaching and learning of science?
2. What do you think about learning in small groups?
3. What do you think about the effectiveness of concept mapping when learning in small groups?
4. Do you think concept mapping is effective in promoting conceptual learning? If so, why? If not, why not?
5. How well do you think the computer-based collaborative concept mapping helped in clarifying students' misconceptions in science learning?
6. Which one do you think is more effective- individual learning or learning in a group? And why?
7. If you could do anything different, what would you do to enhance your student learning and motivation?
8. If you could use concept mapping differently, how would you like to use it?
9. Overall, what do you think of collaborative learning using concept mapping in science?
10. Would you like to recommend the use of concept mapping in your school? If yes, in what ways will you recommend? And if no, why?
11. Is there anything you would like to say about teaching and learning using concept mapping in science?
12. What do you think are factors that can promote the use of concept mapping in science classrooms?
13. What factors may hinder you from using this method/software in your classroom?

Appendix N: Students' Focus Group Discussion guiding questions

Participants

Two groups of 5 students each from each intervention classroom (Total 10 students)

Objectives

1. To explore students' views, perceptions, and experiences of using CCCM in their classroom. To explore students' experience about the science teacher's work (roles and responsibilities), teacher-student and student-student relationships and changes in the classroom environment.
2. To explore difficulties faced by students while using CCCM or concept mapping in their classrooms.

Discussion questions

1. What do you understand by a concept map and how do you draw or prepare a good concept map?
2. What do you think (views) about learning science using concept maps?
3. How did you find (experience) learning science using CCCM in small groups?

   In what ways did learning science using concept maps in small groups help you better understand a scientific concept/content/idea?
4. Did you find any differences between your individual concept maps and concept maps produced by your group?

   And did you find a difference between paper-pencil (manual) concept maps and a concept map produced using computer software? (Give an example)
5. Overall, how have you found (experience) learning science in a different way using concept maps in small groups?
6. What do you think of your science teacher's work (for example roles, responsibilities, relationships, interactions) in the classroom over the last 10 weeks?
7. How did you find relationships (e.g. roles, responsibilities, interactions) among students in your group and in the class during last 10 weeks?
8. How do/did you overcome/settle down any disagreement or difference of opinion (if any arise/arouse) while working in group?

9. What changes have you observed in methods of teaching and learning used while you studied science over the last 10 weeks?
    a. Was this different from what you experienced before?
10. What changes have you observed in the classroom learning environment (students' and teachers' activities overall) in last 10 weeks?
11. Is there anything else you would like to say about learning science using concept mapping in groups and class?
12. Have you encountered any difficulties using CCCM in your group or in the class? If yes, can you please explain giving an example from your experience?
13. What factors do you think can help CCCM use in science classrooms?
14. Can you list/mention some factors that can make CCCM use in science classrooms difficult for students and teachers?

Appendix O: Comparison of psychological experimentation, ethnography and design-based research

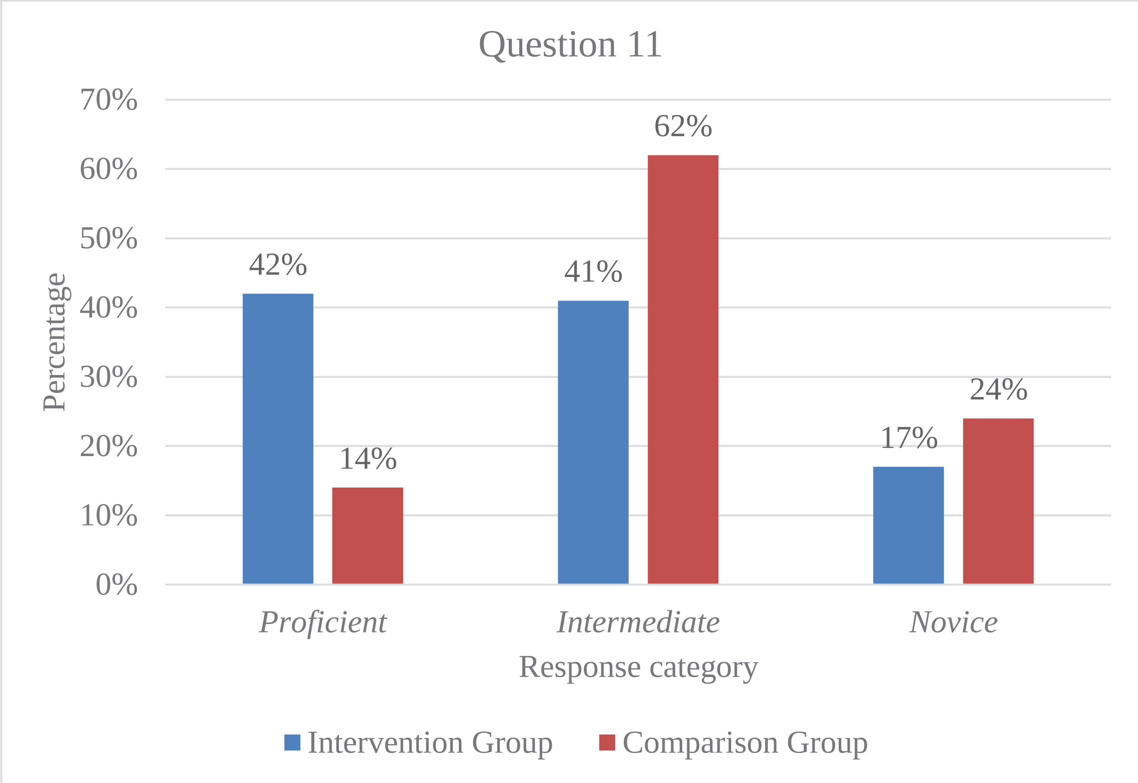
Adapted from Soong (2010, p. 82)

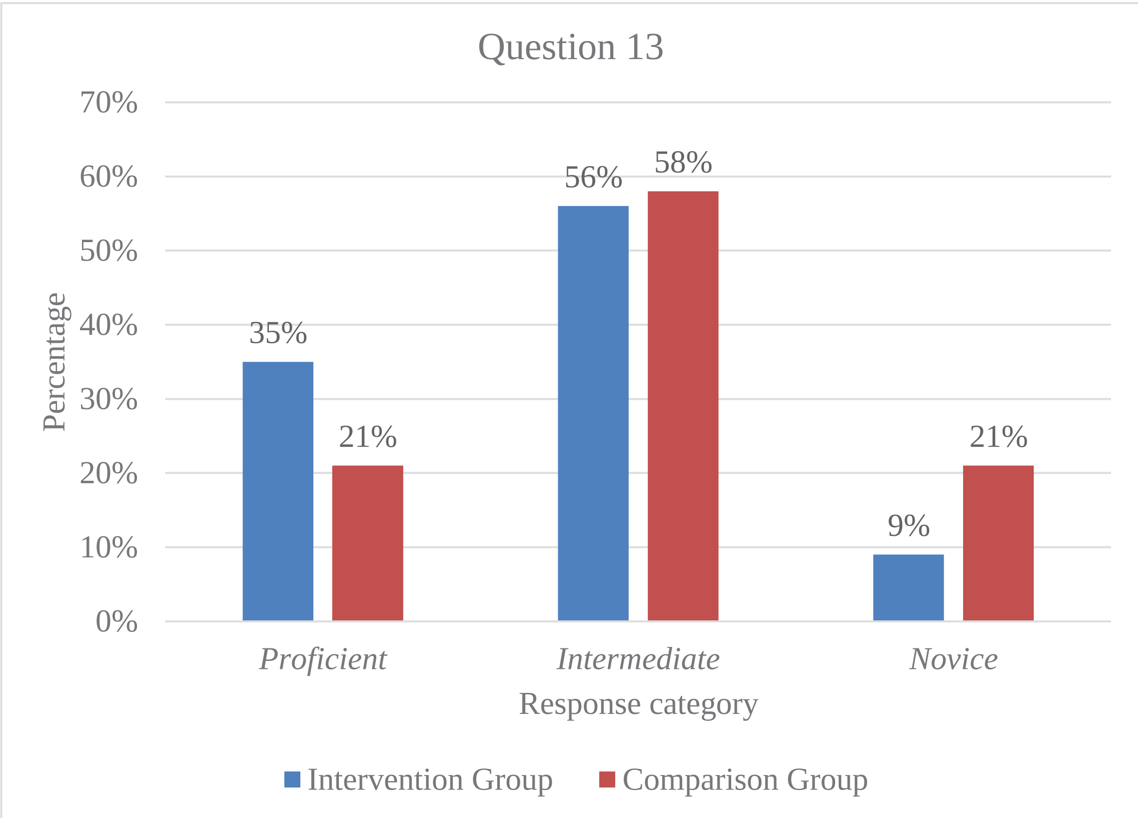
Category	*Psychological Experimentation*	*Ethnography*	*Design Experiments/ Design-based Research*
Location of research	Conducted in controlled (e.g. laboratory) settings	Occurs mainly in real-life (e.g. classroom) settings	Occurs mainly in real-life (e.g. classroom) settings
Complexity of variables	Frequently involves a single or a couple of dependent variable	Involves multiple variables, including climate (e.g. available resources), outcome (e.g. learning of content) and system (dissemination) variables	Involves multiple dependent variables, including climate (e.g. available resources), outcome (e.g. learning of content) and system (dissemination) variables
Focus of research	Focuses on identifying a few variables and holding them constant so as to uncover casual relationships	Focuses on characterising the situation in all its complexity, with a goal of describing particular areas of interest	Focuses on characterising the situation in all its complexity, with a goal of bringing about change and improvements
Role of participants	Treats participants as subjects	Participants are specific individuals with specific stories to share	Involves different participants in different stages of the design experiment (e.g. teachers in the initial design; teachers and students *in situ*)
Unfolding of procedures	Uses fixed procedures	No specific procedures are to be followed, as it is part of a naturalistic study of culture	Starts with a framework, but involves flexibility and design revisions depending on their success in practice in consultation with the participants

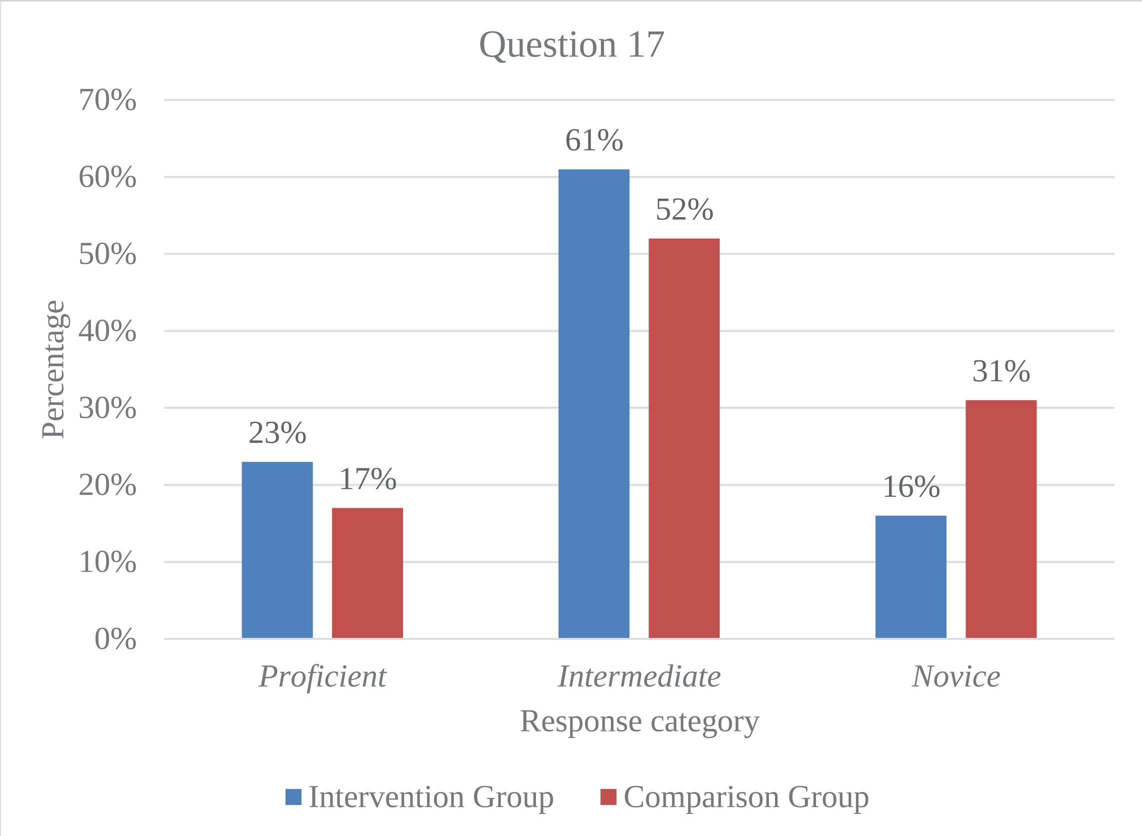
Iteration extent	The fixed procedures are usually repeated for different subjects	No 'iteration' as it is an in-depth study of a particular culture	Highly iterative process involving input from the same participants
Amount of social interaction	Isolates learners to control interaction	Complex social interactions between actors in the system (e.g. students, teachers, researchers, etc.)	Frequently involves complex social interactions between actors in the system (e.g. students, teachers, researchers, etc.)
Characterising the findings	Focuses on testing hypotheses	Involves writing a thick descriptive of multiple accounts of the same culture as experienced by different individuals	Involves looking at multiple aspects of the design and developing a profile that characterises the design in practice

Appendix P: Visual description of the ATS9 response percentages

1. For LOCS responses (Table 4.10)



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50%
40%
30%
20%
10%
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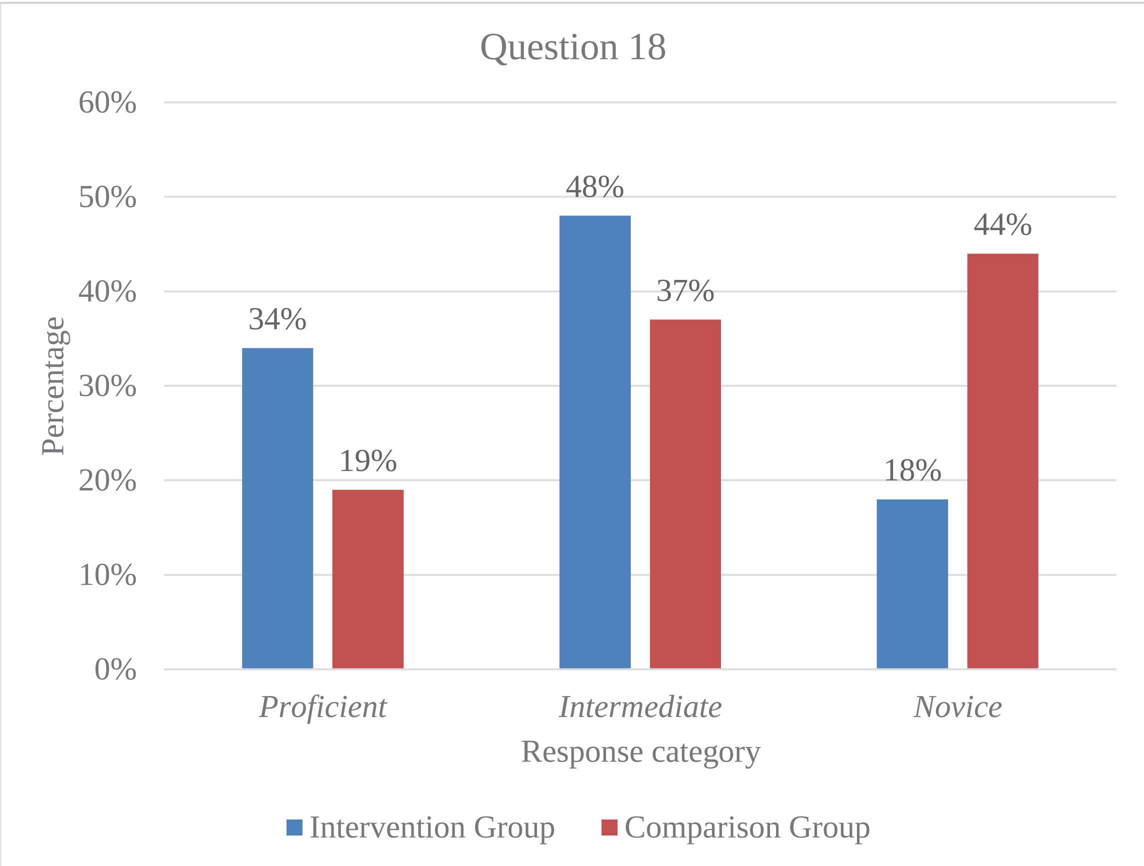
Percentage
61%
52%
23%
17%
31%
16%
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group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34%
19%
44%
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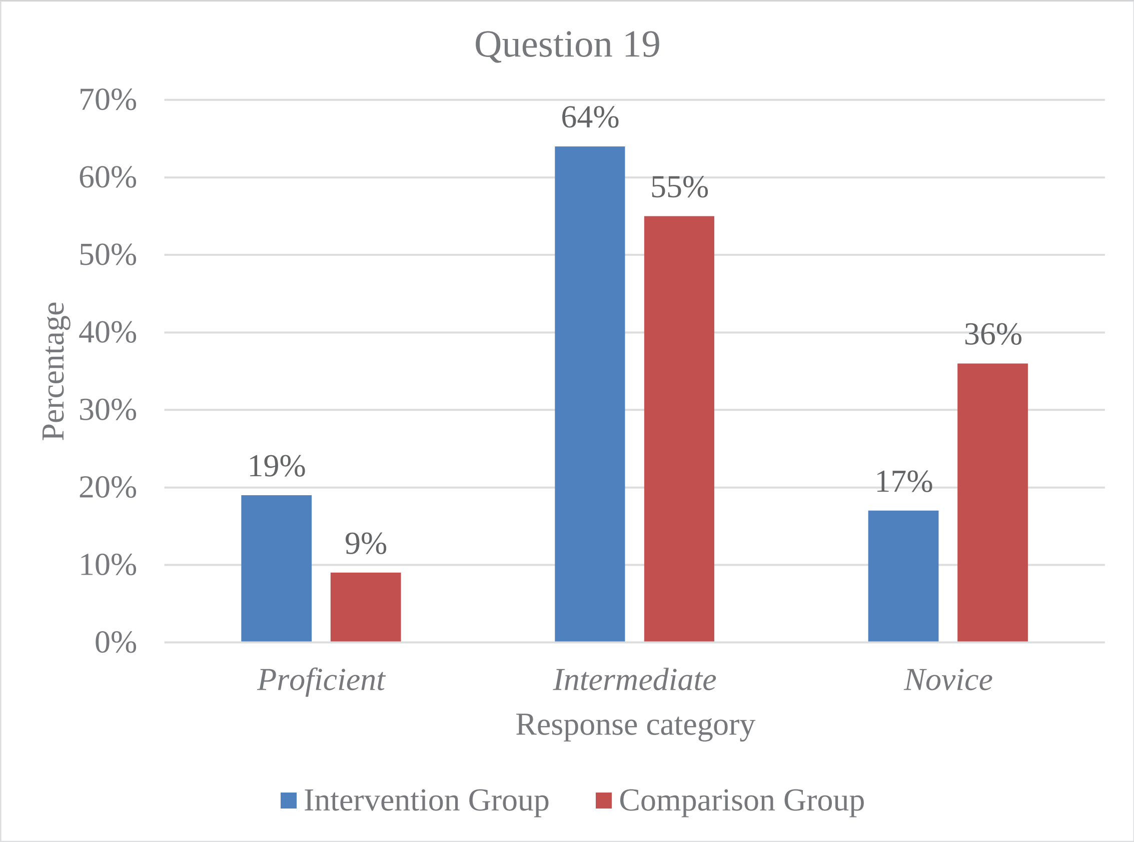
Intermediate
Novice
Response category
Intervention Group
Comparison Group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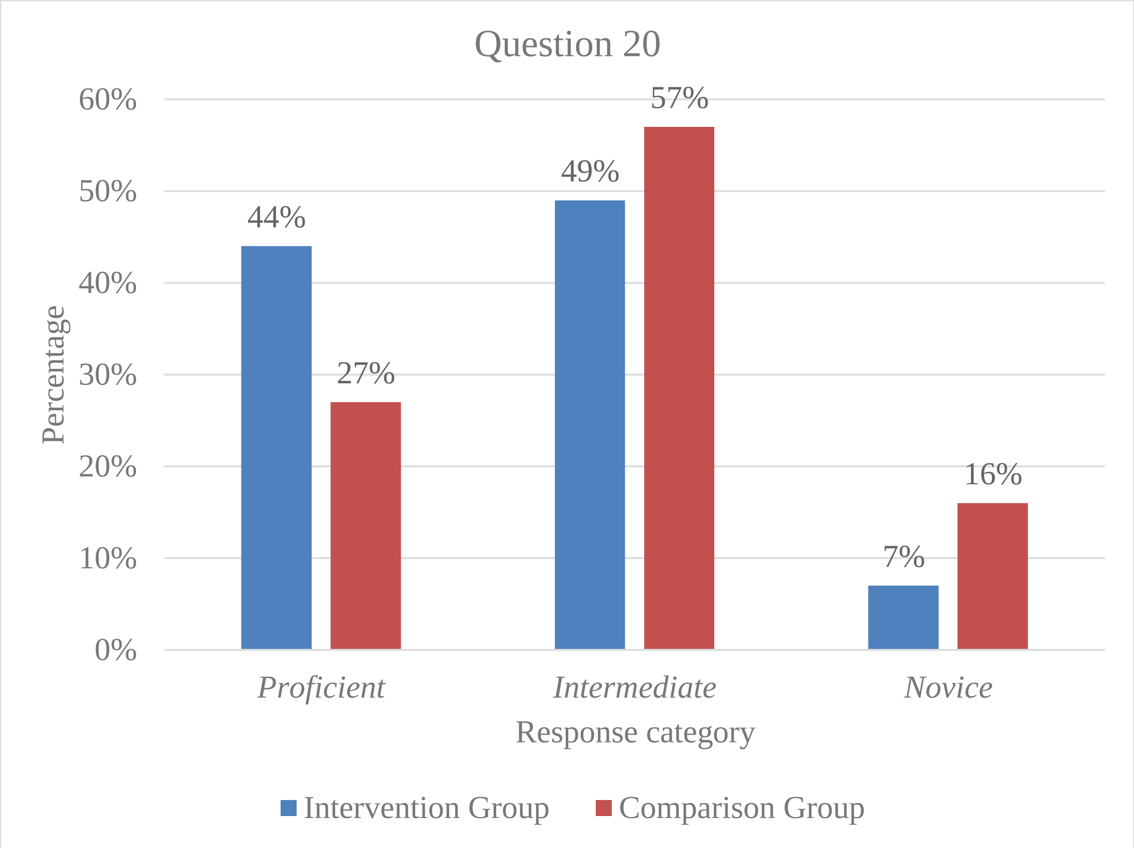
Intermediate
Novice
Response category
Intervention Group
Comparison Group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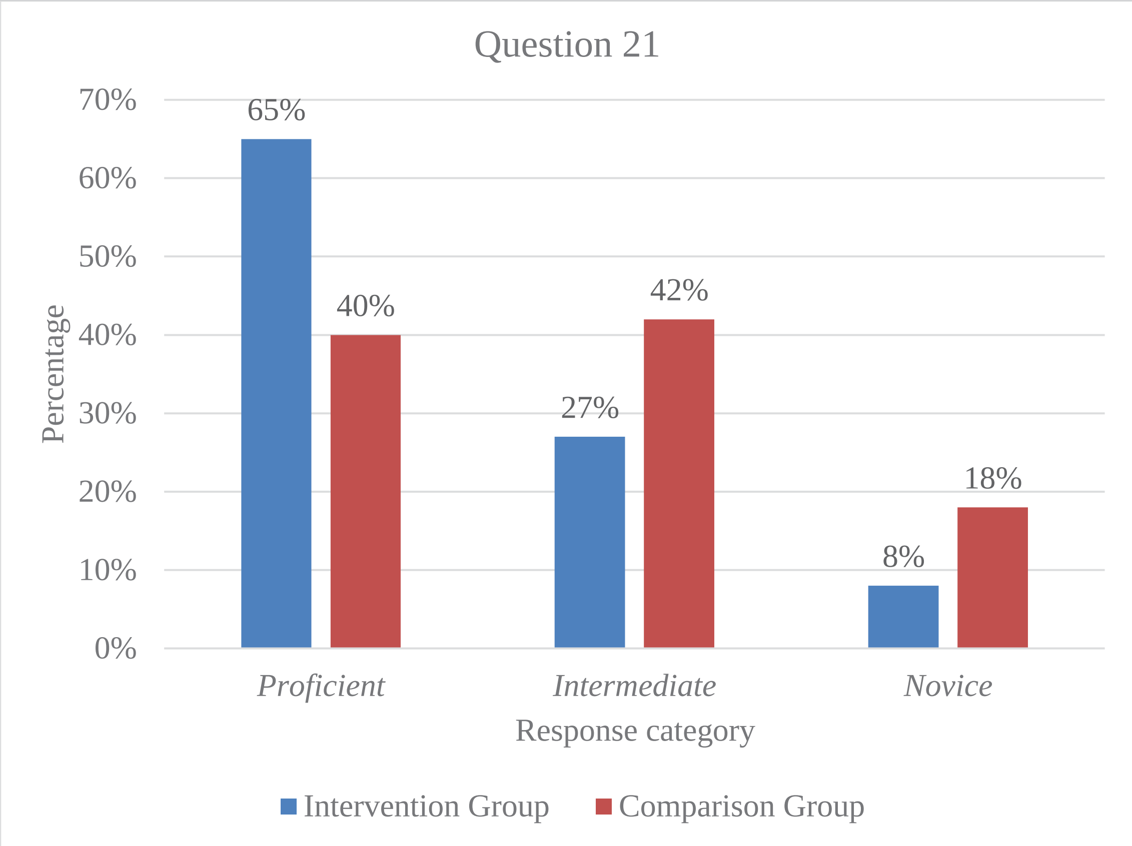
Novice
Response category
Intervention Group
Comparison Group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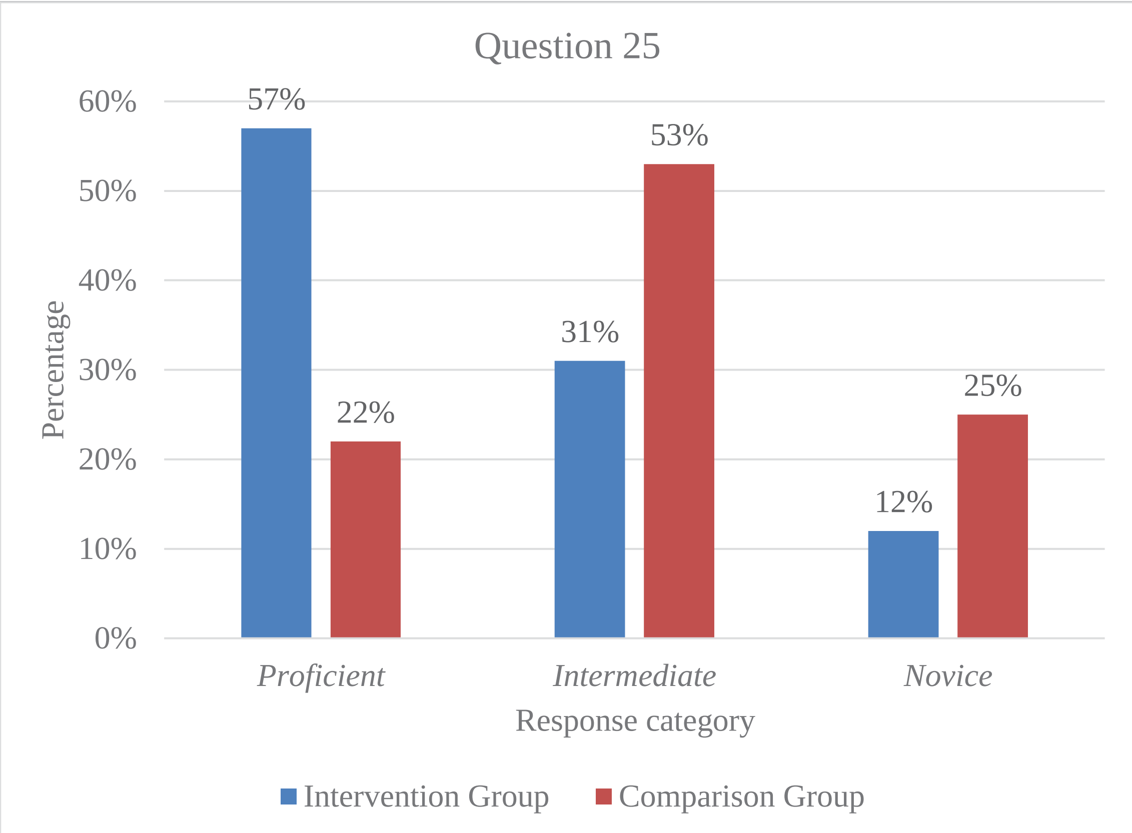
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group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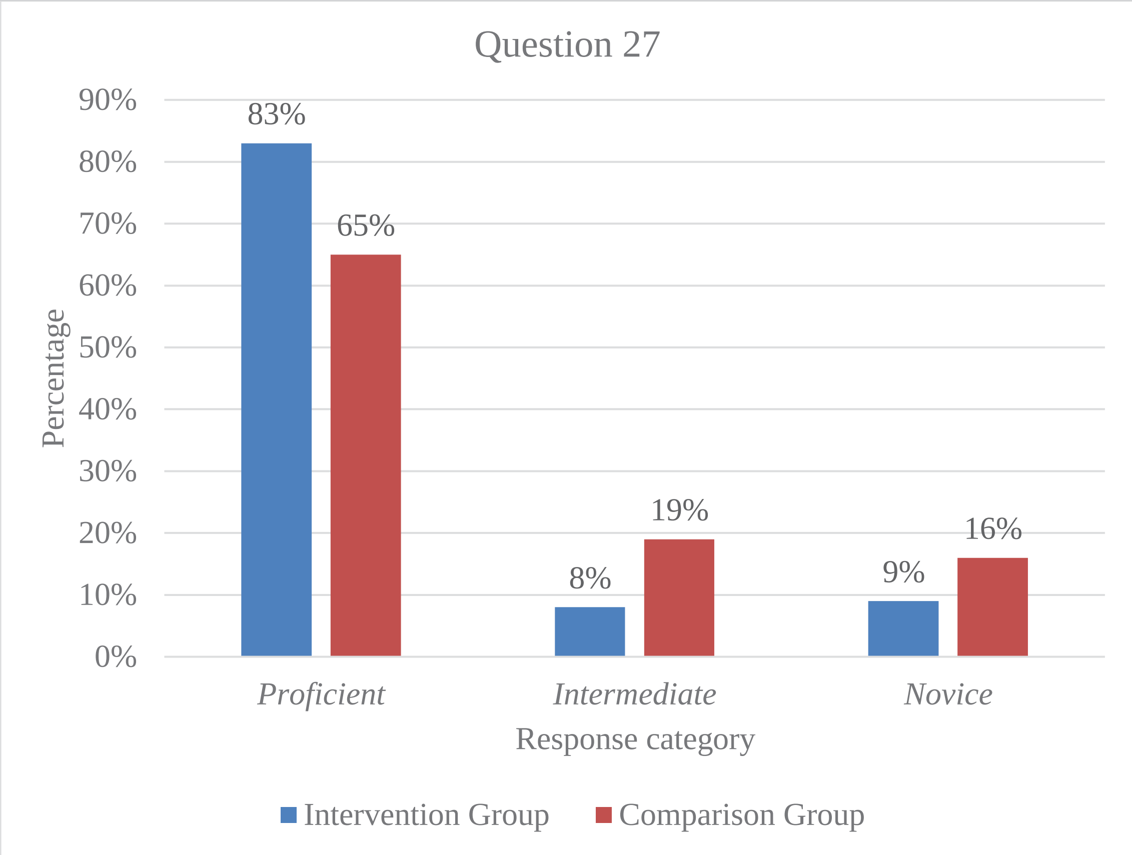
Intermediate
Novice
Response category
Intervention Group
Comparison Group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20%
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Percentage
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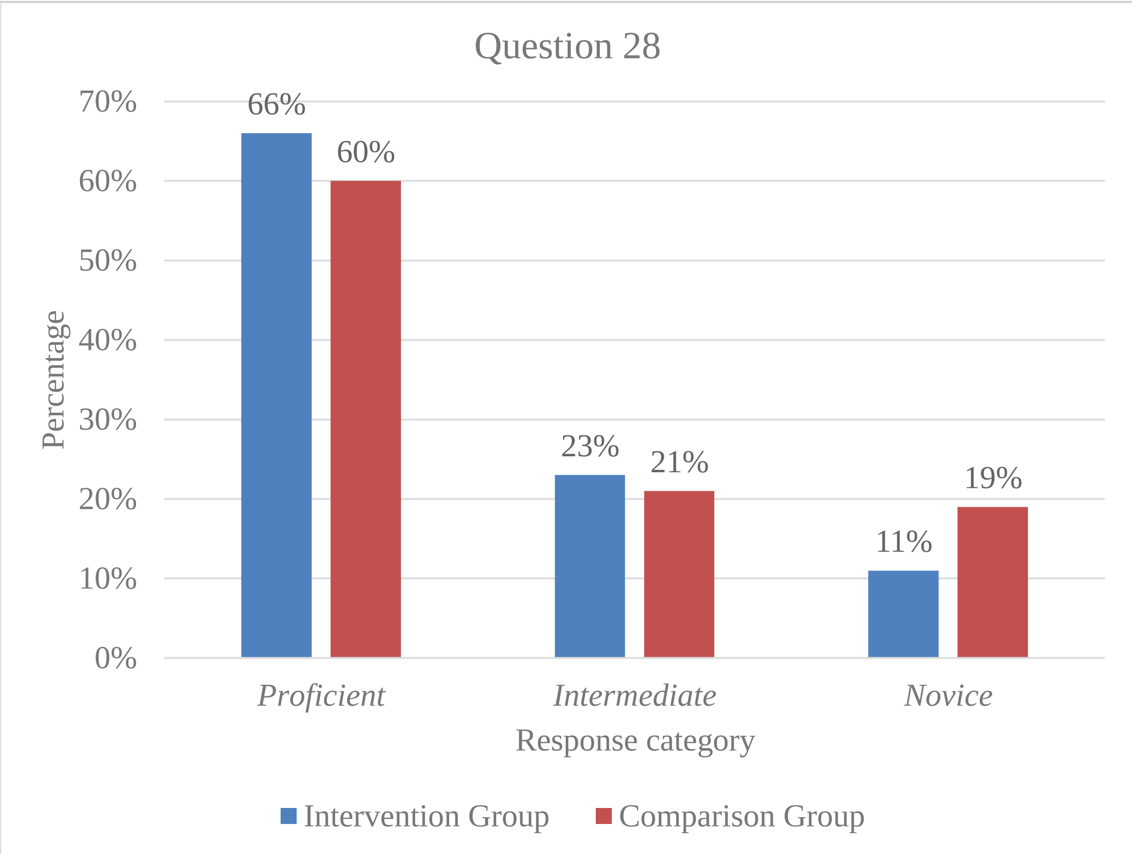
9%
16%
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group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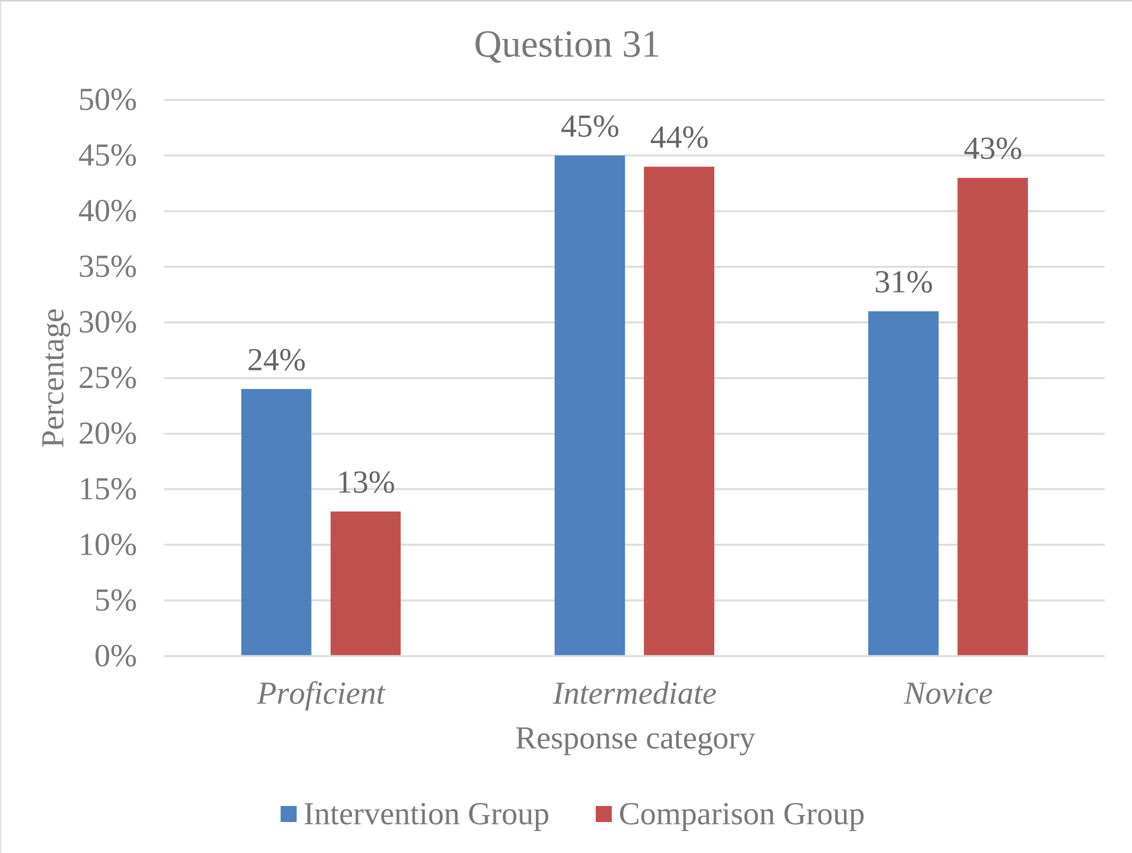
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group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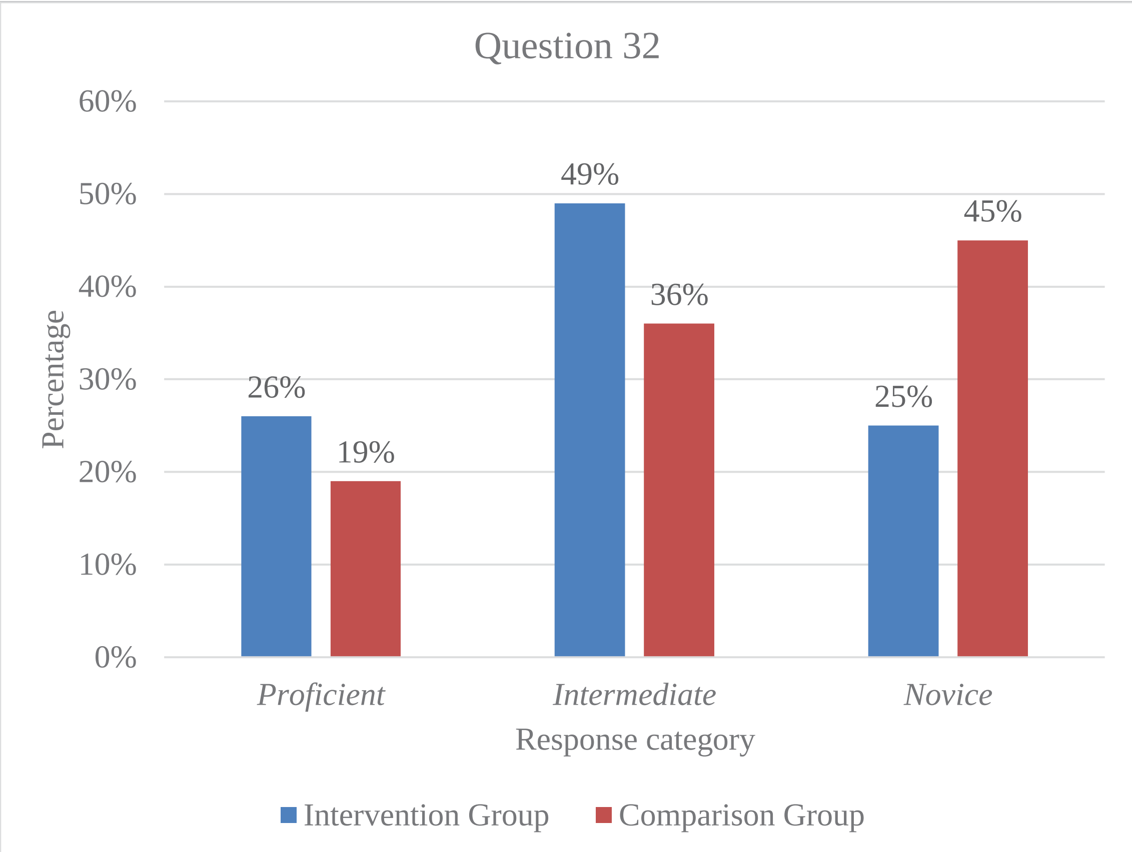
31%
43%
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group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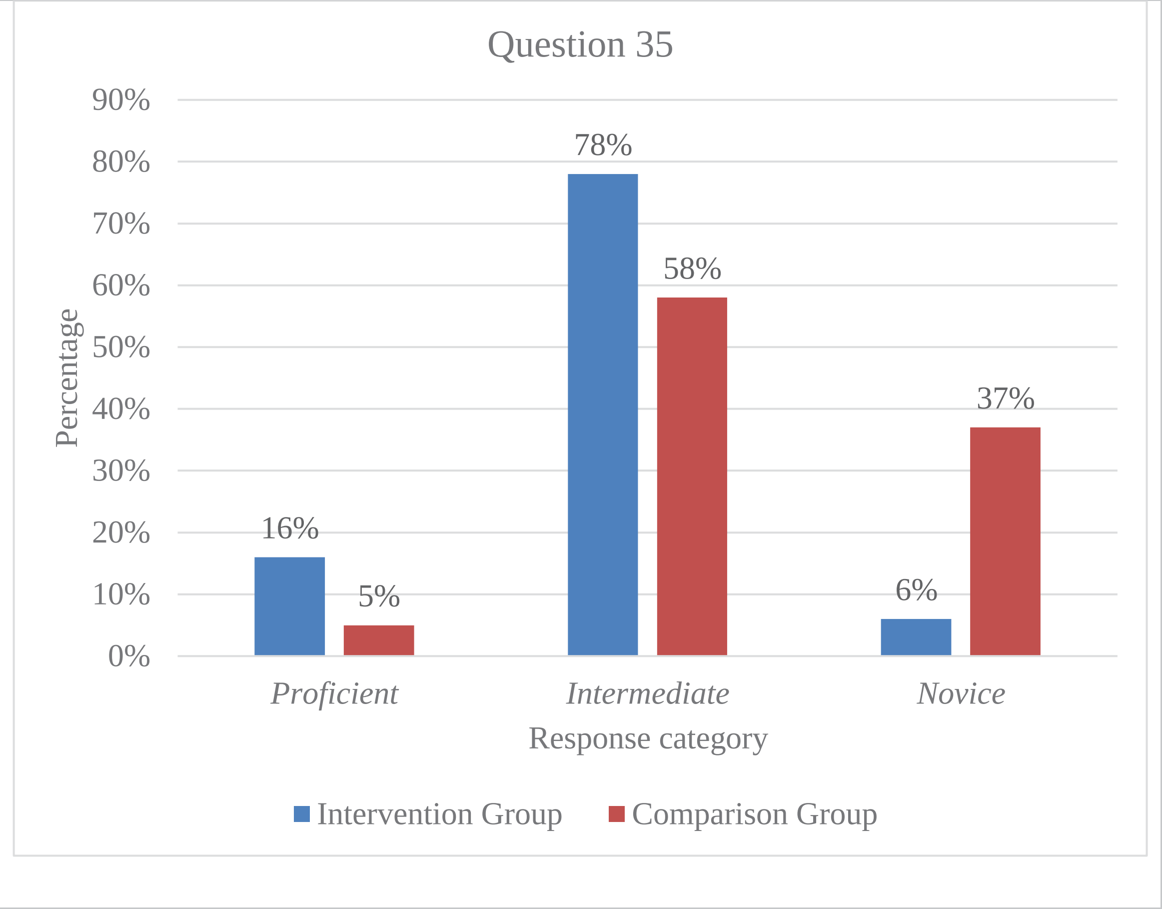
Novice
Response category
Intervention Group
Comparison Group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Percentage
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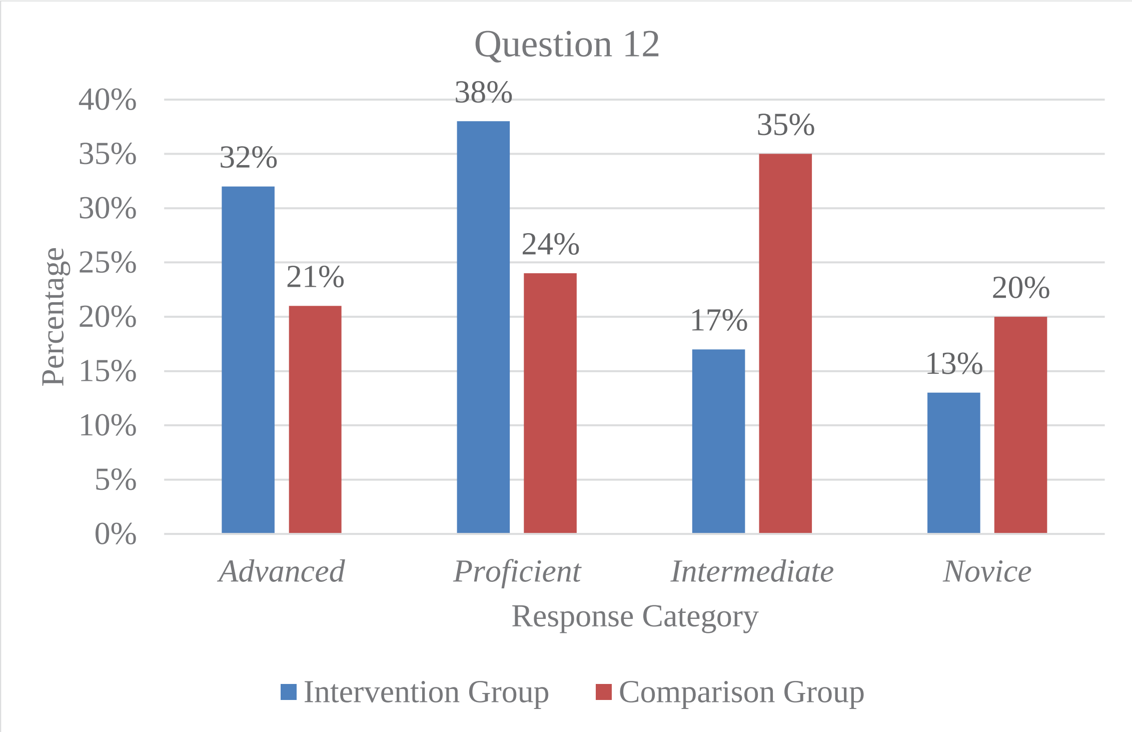
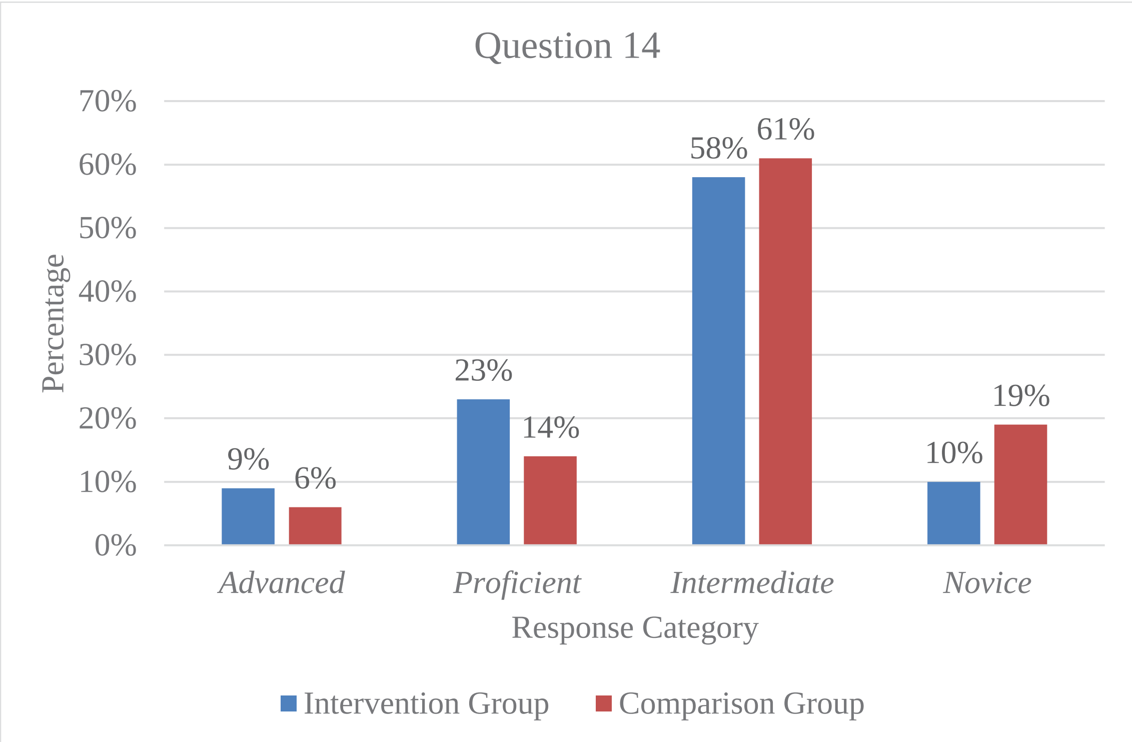
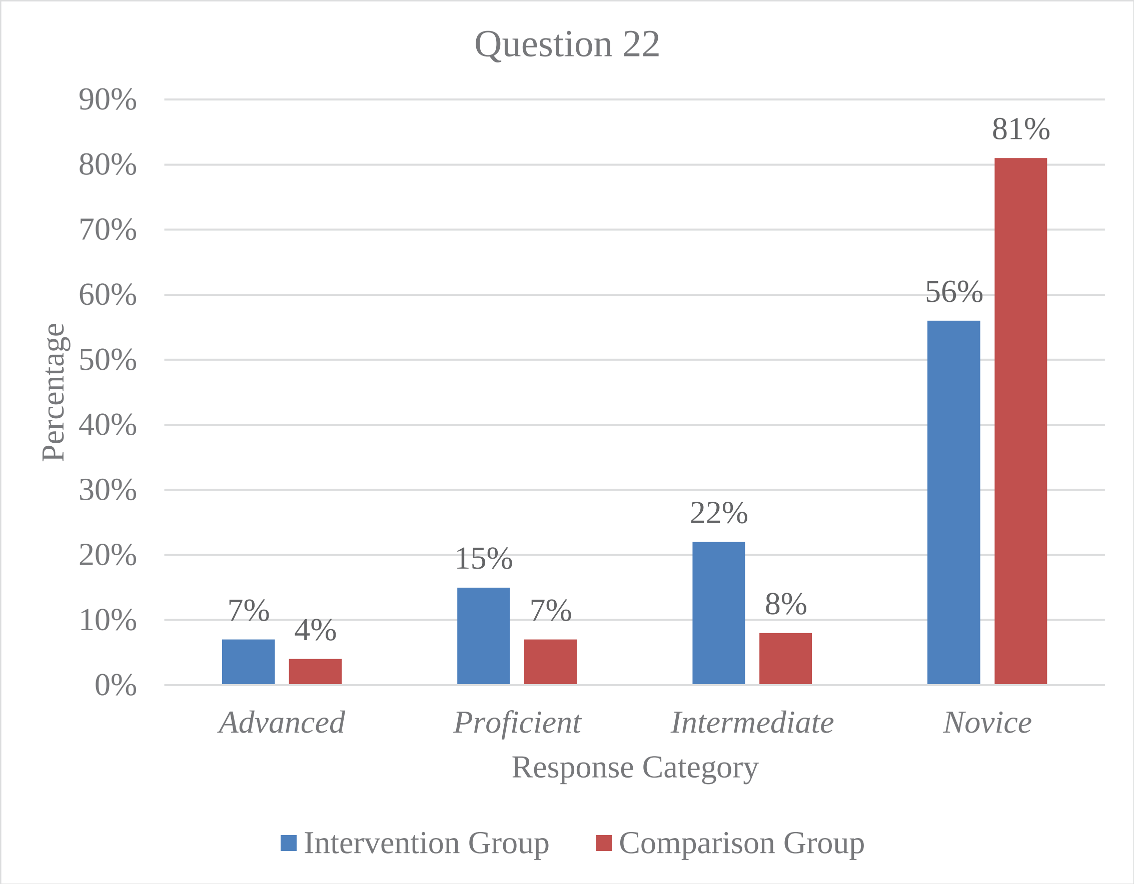
6%
Proficient
Intermediate
Novice
Response category
Intervention Group
Comparison Group

For HOCS Responses (Table 4.13)



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10%
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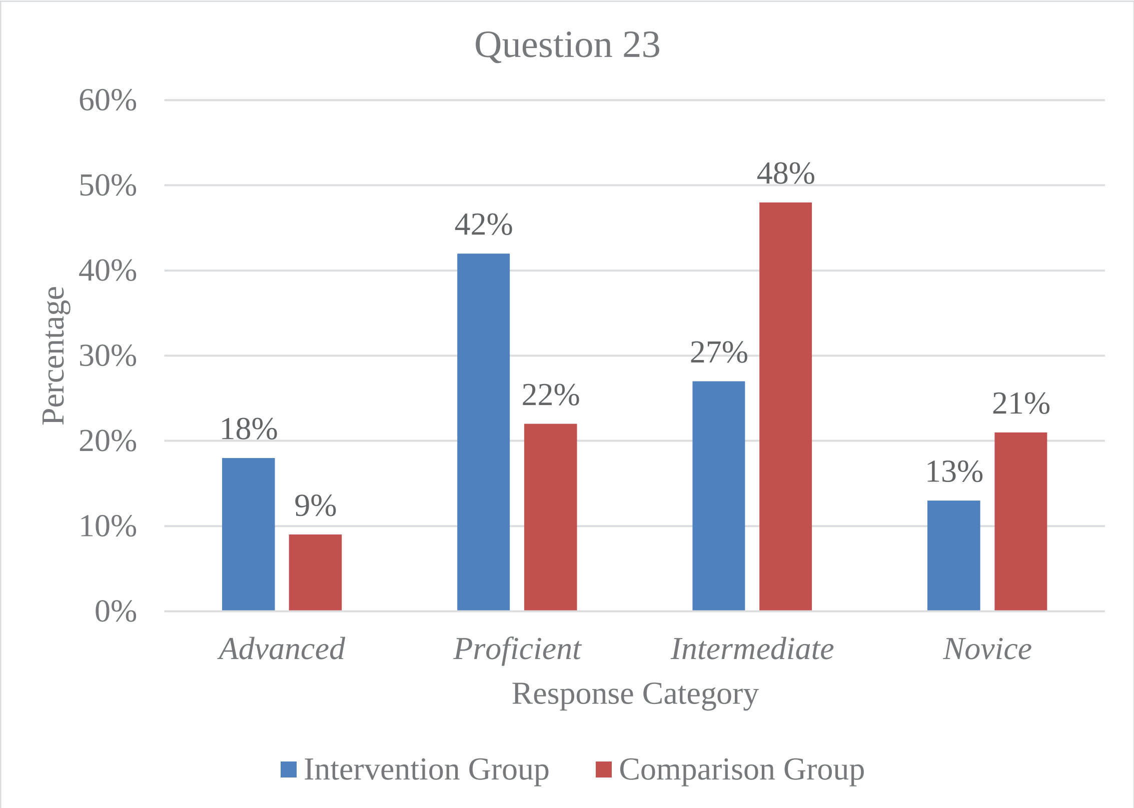
Advanced
Proficient
Intermediate
Novice
Response Category
Intervention Group
Comparison Group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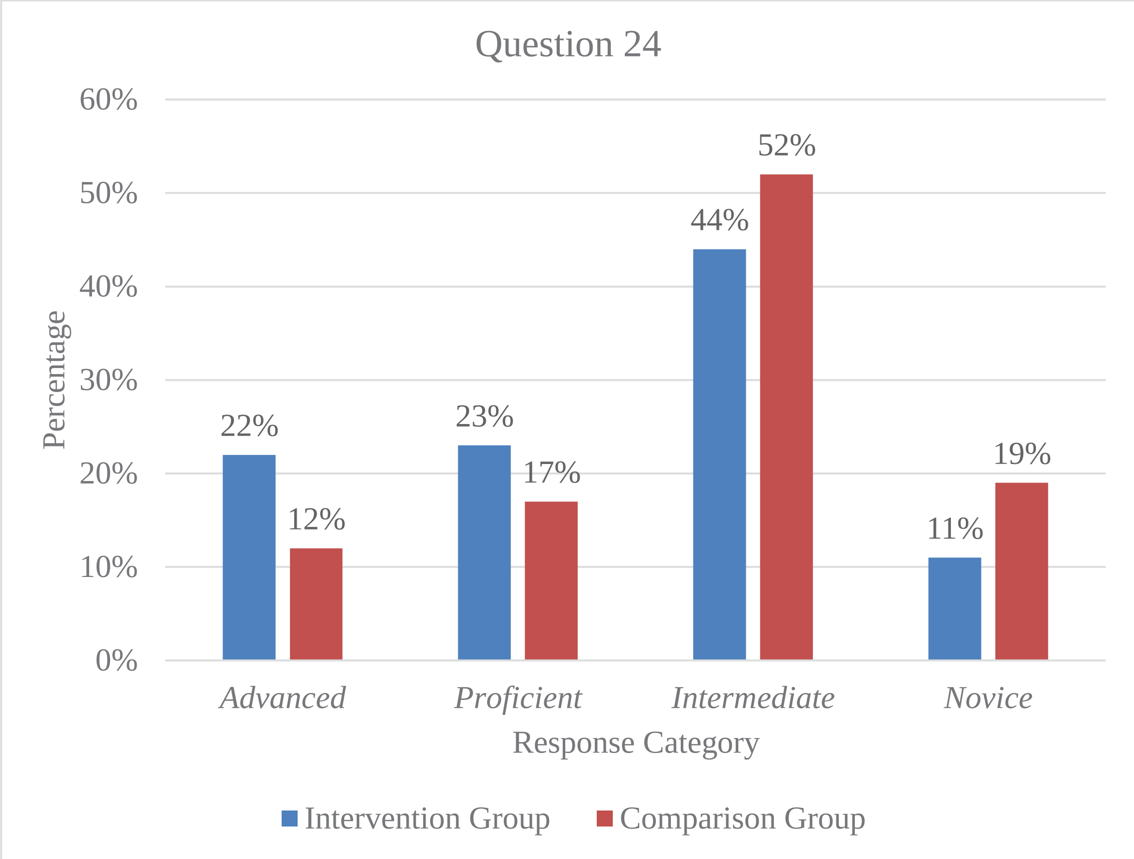
Advanced
Proficient
Intermediate
Novice
Response Category
Intervention Group
Comparison Group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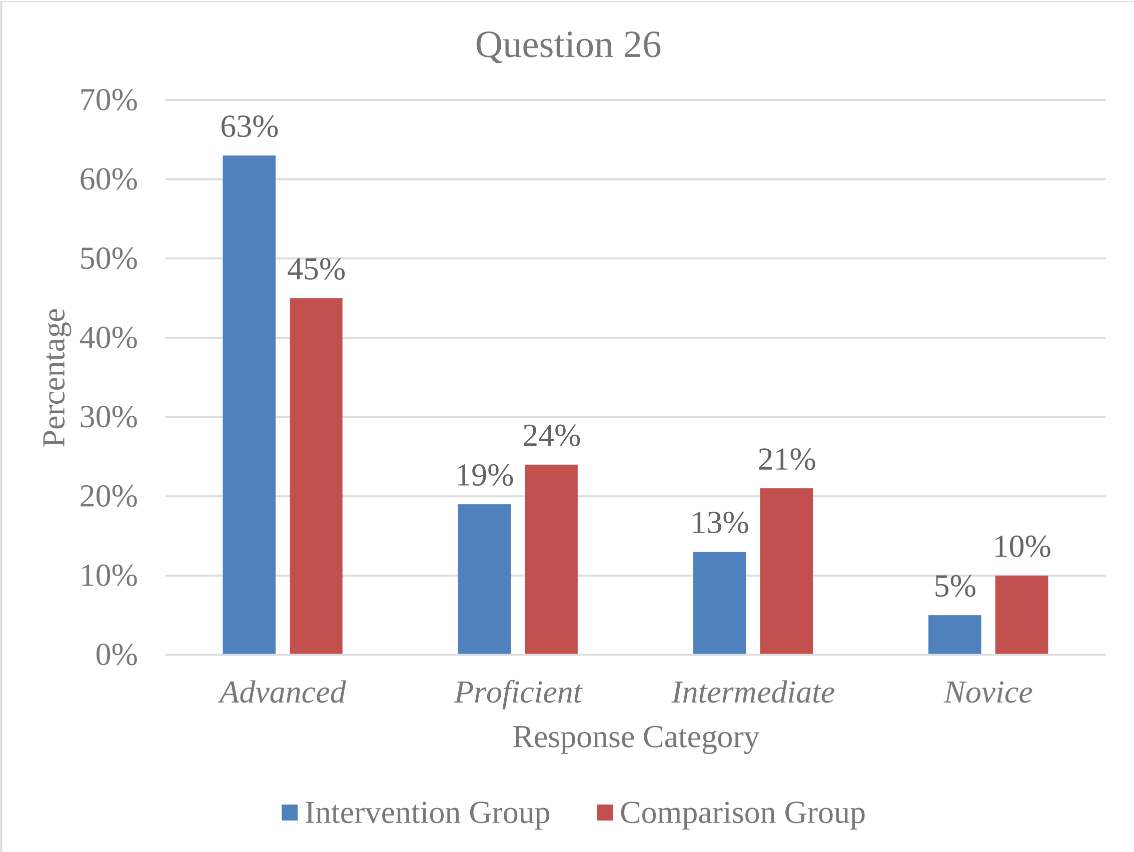
Novice
Response Category
Intervention Group
Comparison Group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Proficient
Intermediate
Novice
Response Category
Intervention Group
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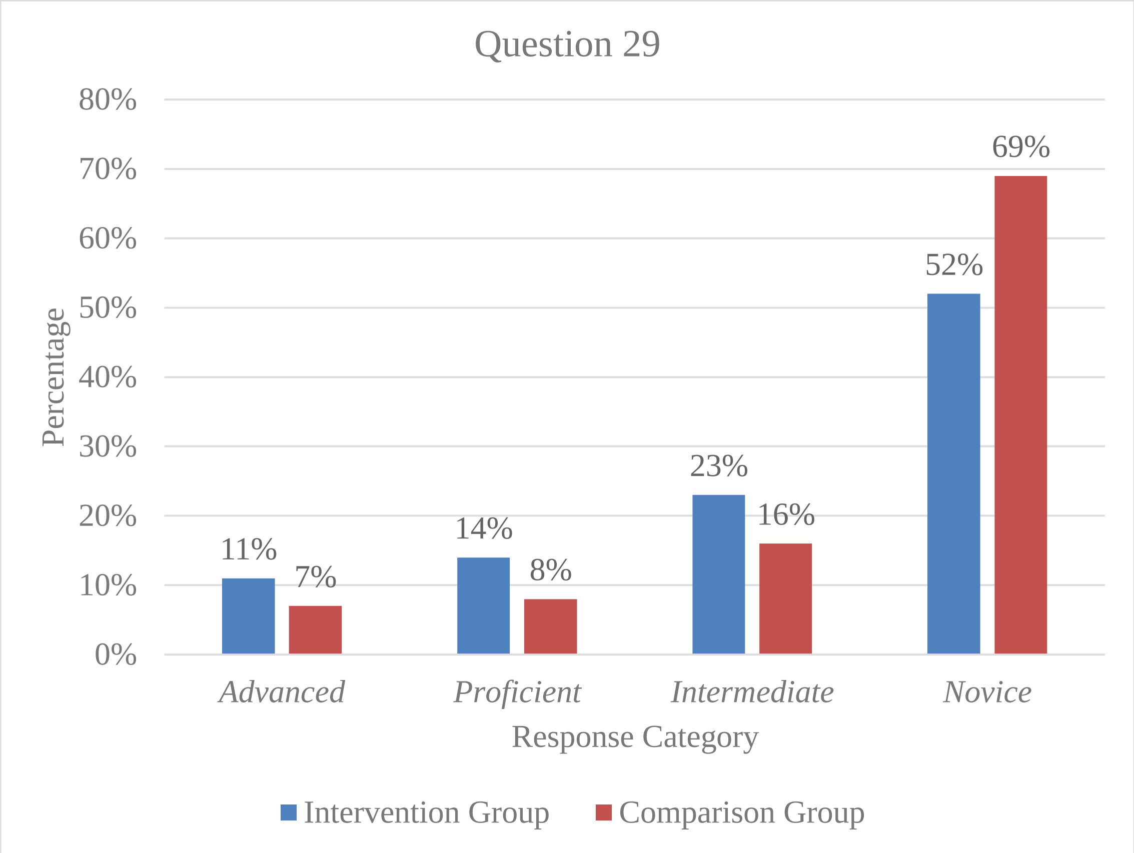
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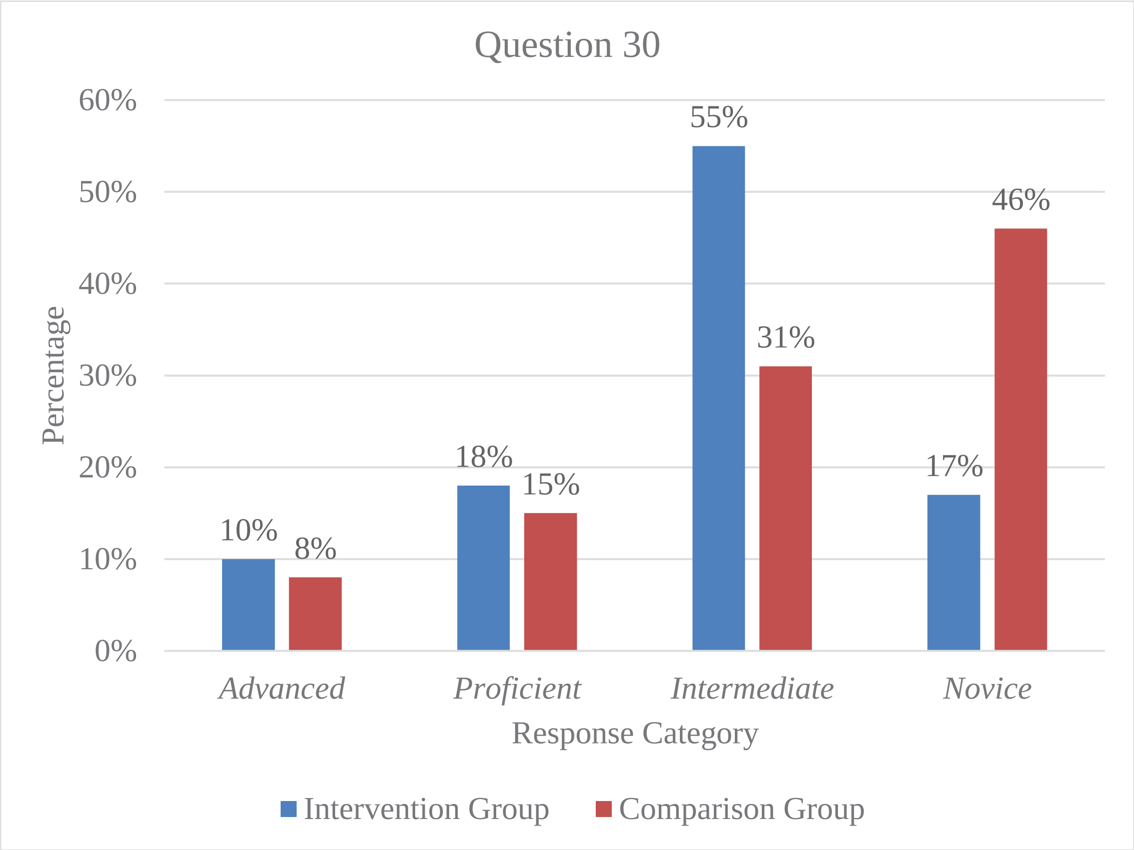
Advanced
Proficient
Intermediate
Novice
Response Category
Intervention Group
Comparison Group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Novice
Response Category
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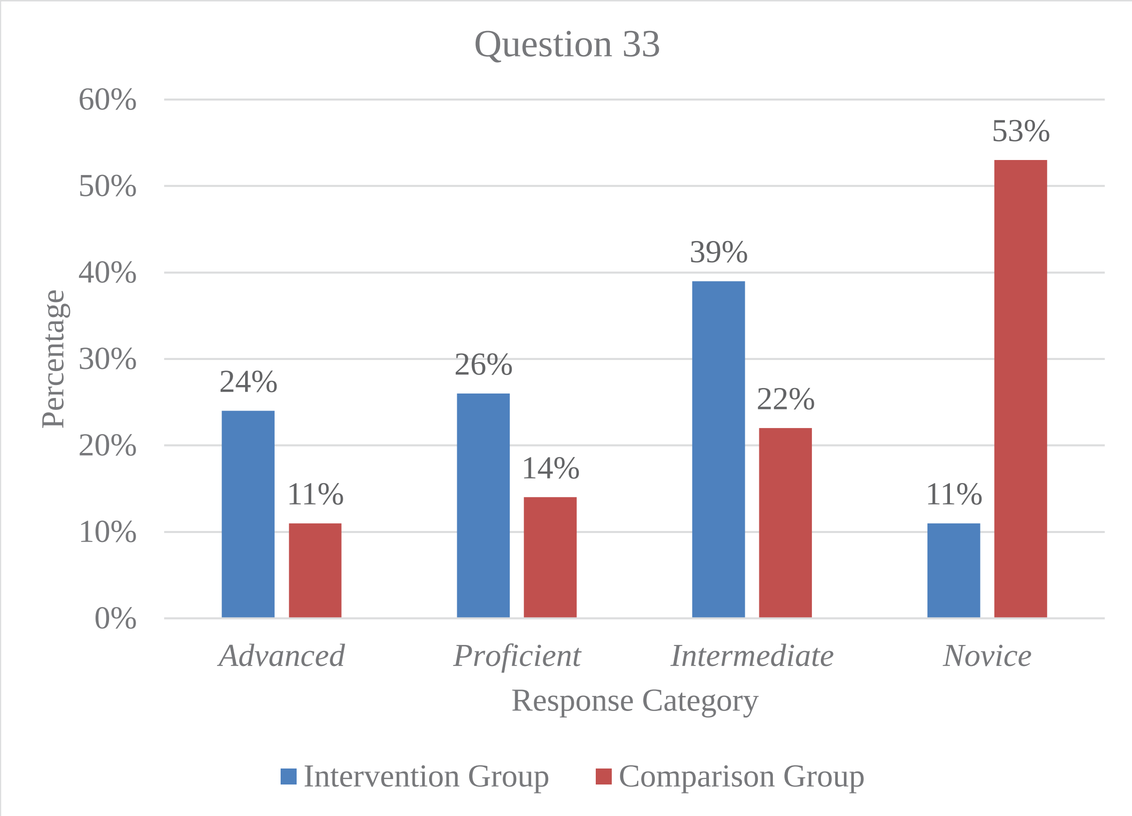
Comparison Group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Percentage
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Advanced
Proficient
Intermediate
Novice
Response Category
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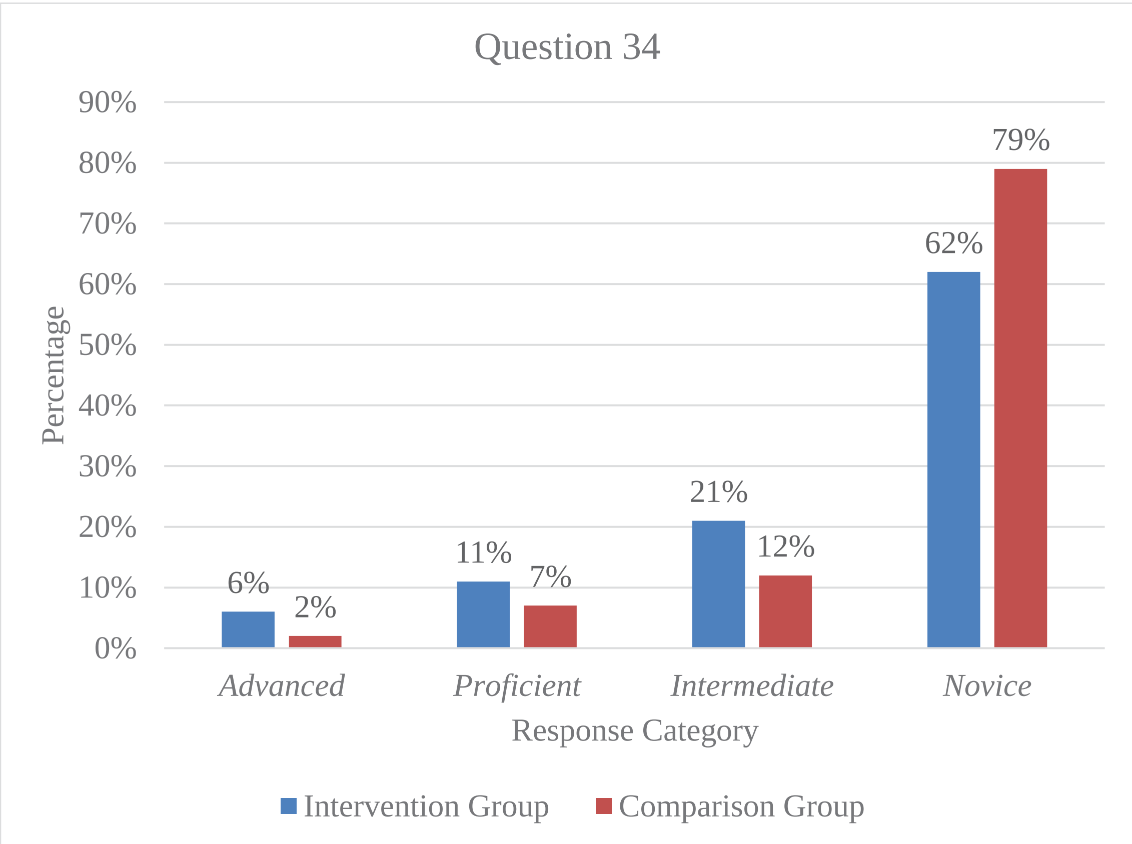
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Percentage
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2%
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7%
21%
12%
62%
79%
Advanced
Proficient
Intermediate
Novice
Response Category
Intervention Group
Comparison Group